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Sir: This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(c).

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LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)

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SAW SINGULATION

The present invention generally relates to an improved apparatus and method for singulating a substrate into a plurality of integrated circuit devices (e.g., dies, unpackaged chips, packaged chips, and the like). The system described herein is particularly suitable for singulating leadless packages such as QFN. Although directed at leadless packages, the system is also suitable for singulating surface mount devices such as chip scale packages, ball grid arrays (BGA), flip chips, and the like.

A singulation procedure is typically performed to separate integrated circuit packages such as IC chips from a substrate such as a circuit board. During singulation, the substrate is typically held in place while one or more saw blades cut straight lines through the substrate to form the individual integrated circuit packages. Although dicing with saw blades has worked well, continuing advancements in the industry have tested the limitations of saw singulation.

There is continuing pressure in the semiconductor packaging industry to pack more features into minimal space. One result has been the growth of CSP (chip scaled packages) and near CSP packages offering high performance electrical characteristics, enhanced thermal management and small volume displacements.

While initially cost prohibitive, these packages have been cost enabled by the advent of matrix array processing. These arrays address the two largest cost drivers of high performance packaging: substrate and capital equipment costs.

The reduced pitch between devices minimizes substrate waste and maximizes the device density, therefore, fewer substrates are consumed and material costs can be amortized over more devices. Similarly, the increased number of devices per substrate allows manufacturers to produce more parts per manufacturing cycle and amortize the cost of capital over more devices.

Due to the high benefit to cost ratio, the industry migration to matrix array processing has been swift. Over the past three years, many QFP designs have been supplanted by matrix array FBGA. Now SOIC devices are shifting to QFN (Quad Flat Pack No

Lead packages). While laminate substrates continue to ramp, the copper lead frame based QFN package has been stifled by the inability of saw singulation to deliver cost effective results.

Cutting small devices is particularly problematic for saw singulation. When device dimensions are small as for example less than 3mm x 3mm, vacuum fixtures are unable to retain the small devices during sawing, with consistency. As the saw blade passes through a device, it is both rotating and translating relative to the device under process. The resulting force vectors have both vertical and shear components. As the shear component overwhelms the holding force of the vacuum fixture, the singulation yield drops due to non-conforming geometries, damage, or lost parts. As feed rates increase, the magnitude of the shear component increases commensurately and magnifies the device retention problem. Therefore, feed rates are minimized to protect yields. The result, however, is lower throughput.

QFN singulation requires specially formulated blades that must constantly expose new diamonds to the cut interface. As the diamonds remove material, they are "dulled" by the materials used in the substrate and must be sloughed-off as the blade wears at a higher-than-normal rate. The balance between blade wear and cut quality is a delicate trade-off requiring costly technology to extend blade life while minimizing burrs and chips.

Figs. 1A-1E are illustrations showing leadless integrated circuit packages before and after being singulated from a substrate, in accordance with one embodiment of the present invention. Figs. 1A and 1B show a substrate 32 before singulation. As shown, the substrate 32 is formed by a plurality of integrated circuit packages 33. Although not a requirement, the packages 33 are generally formed in rows and columns on the substrate 32. The number of packages formed on the substrate generally depends on both the size of the substrate and the size of each of the packages. Furthermore, the number of leads in each of packages generally varies according to the specific needs of the packages. Furthermore, the integrated circuit packages 33 may be positioned in one or more closely packed groups 34. Substrate 32 also generally includes locator holes 36 which are used for various alignment procedures. Fig. 1C shows a group 34 of leadless integrated circuit packages 33 after

being cut from the substrate 32. The group 34 may correspond to any of the four groups 34 shown in Figs. 1A and 1B. Figs. 1D and 1E show a single leadless integrated circuit package 35 after being separated from the group 34.

In one particular embodiment, the substrate 32 corresponds to those substrates that contain Quad Flat No Lead (QFN) packages. QFN packages generally refer to leadless packages with peripheral terminal pads and an exposed die pad. QFN packages may be used in a variety of applications including cell phones, personal digital assistants, portable music players, portable video players and the like. QFN substrates typically include a copper carrier A, and a mold compound B through which the saw blade cuts in order to singulate the individual QFN packages 33 from the substrate 32.

Attention is now directed to Figs 2A- 2I, which lay out a QFN gang cutting high throughput process including a case history, a standard process for QFN and some of its limitations, initial tests and findings, results and added modifications, solution to blade breakage, further developments, spacers and bracket changes, and the like. As shown in Figs. 2A-2C, current dicing processes suffer from such limitations as low throughput, low feed speed, blade breakage, etc. Increasing throughput has tradeoffs such as reduced blade life and cut quality (as seen in the photographs of Fig. 2C). The layout of current processes also contributes to problems such as blade breakage. For example, Fig. 2E illustrates one scenario in which scrap from the cutting process is reflected off location pins (used to locate and hold substrates in place during dicing) and back onto the cutting blade, resulting in damage and wear to the blade.

In order to solve these problems and increase throughput, various embodiments incorporate features of the invention such as those listed in Fig. 2I. For example, nests holding the substrate are modified to eliminate the presence of locator pins during dicing, spacers are modified to reduce the problem of imbalance caused by water retained within them, and nozzles are introduced that provide for better flow of fluid over the cutting blades. A fine adjust system is also introduced to better orient these nozzles toward the blades, and the composition of the fluid used during dicing is also modified. These and other features of the invention are discussed below.

Embodiments of the invention are discussed below with reference to the Figures. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these figures is for explanatory purposes as the invention extends beyond these limited embodiments.

Fig. 3 is a simplified block diagram of a substrate processing system 100, in accordance with one embodiment. The substrate processing system 100 may be used to process packaged devices contained on a strip, carrier or substrates of various types including circuit boards, film, metal on ceramic based substrates, and the like. By way of example, the substrate processing system may be used to process the strip shown in Figs. 1A and 1B in order to produce the leadless packages shown in Figs. 1C-1E. The substrate processing system 100 generally includes a cassette onload subsystem 102, a substrate loading subsystem 104, and a singulation subsystem 106.

The cassette onload subsystem 102 is configured to feed a plurality of substrates 108 to the substrate processing system 100. The plurality of substrates 108 are typically grouped together and delivered in a cassette 110 to the system 100. The cassette 110 is placed in the cassette onload subsystem 102 and thereafter each of substrates 108 is fed to the substrate loading subsystem 104. By way of example, an individual substrate 108 may be fed to the substrate loading subsystem 104 via a pick and place machine (or similar carrier) that picks up the substrate 108 from the onload subsystem 102, moves the substrate 108 to the substrate loading subsystem 104, and places the substrate 108 in the substrate loading subsystem 104.

The substrate loading subsystem 104 is configured to load an individual substrate 108 (see Figs. 1A and 1B) onto a nest 112. The nest 112 may for example be one of the nests shown and described in Patent Nos.: 6,187,654 and 6,325,059, which are herein incorporated by reference. The nest 112 may also be modified from those shown in the previous Patents. For example, the nest 112 may not include locator pins for aligning the substrate 108 to the nest 112 as shown therein, but rather locator holes 114 that accept locator pins therethrough. As mentioned, the locator pins may present problems during the singulation procedure. For example, they may interfere with the cutting device or they may trap scrap material, which causes the blades of the cutting device to break.

In this particular embodiment, the locator pins 116 are positioned on a pre-stage pin holder 118 rather than the nest 112. As such, the pins 116 do not interfere during singulation because they stay with the prestage pin holder 118 located within the substrate loading subsystem 104 and not with the nest 112. The nest 112, however, does include corresponding through holes 114 for receiving the locator pins 116. These, however, do not cause problems during singulation as they do not mate with substrate 108 during singulation. When the nest 112 is placed on the pin holder 118, the locator pins 116 pass through the through hole 114 and extend or protrude out of the nest 112. The locator pins 116 thereby perform their aligning function as if they were permanently positioned on the nest 112. The nest 112 may include a cover (not shown) in order to secure the substrate 108 in the aligned position relative to the nest 112. The cover may provide a force that sandwiches the substrate 108 between the nest 112 and the cover, thereby preventing the substrate from moving out of the aligned position. Once the substrate 108 is aligned and secured to the nest 112, the nest 112 is loaded into the singulation subsystem 106. By way of example, nest 112 may be loaded by a transfer mechanism (or similar carrier) that picks up the nest 112, and moves it to the singulation subsystem 106.

The singulation subsystem 106 is configured to singulate the substrate 108 or strip of packaged devices into a plurality of individual chips (see Fig. 1C – 1E). The singulation subsystem 106 generally includes one or more sawing devices 120. Each of the sawing devices 120 includes one or more cutting blades 122 for dicing the strip 108 into a plurality of chips or dies. The cutting blades 122 are arranged to rotate about an axis 124 so as to dice the substrate 108 in a particular linear direction. In general, more blades 122 equates to a decreased cycle time. Therefore, a plurality of cutting blades 122 is preferably used in parallel in order to decrease the cycle time of the system. For example, the saw 120 may include two or more cutting blades 122 positioned side by side with gaps therebetween corresponding to the desired width of the singulated chip. This is sometimes referred to as "pitch."

The number of blades 122, as well as the direction of dicing, may be widely varied. The number of blades 122 may generally correspond to the number of chips located in the rows or columns of chips disposed on the substrate 108. For example, in a ten by

ten array the saw assembly 120 may include at least 10 blades 122. This is not a requirement, however, and the number of blades 122 may vary according to the specific needs of each device, i.e., there may be fewer blades 122 than rows of chips or there may be more blades than rows of chips. In the case where there are fewer blades 122 than chips, the system 106 may be arranged to make more than one pass in order to complete the cutting of the substrate 108 in the specified direction.

The sawing devices 120 generally include a motor 126 having a spindle that rotates about the axis 124 to provide rotation for the cutting blades 122. The cutting blades 122 are attached to the spindle via an arbor 128. The arbor 128 includes one or more spacers 130. The cutting blades 122 are placed on the arbor 128 between spacers 130. When locked in place, the spacers 130 hold the cutting blades 122 so that they do not slip when cutting. They are typically locked in place by a locking nut that provide an axial force along the axis 124 of the arbor 128 thereby sandwiching the spacers 130 and blades 122together. The width of the spacers 130 are configured to set the distance between cutting blades 122(e.g. pitch). The motor 126 is typically attached to a spindle housing 132. The spindle housing 132 may be attached a transfer mechanism configured to provide motion such as lowering and raising the sawing device(s) 120.

The sawing devices 120 may include several features for improving the cutting procedure. The sawing devices 120 may for example include a spray nozzle assembly 134 for spraying coolant or lubricant on each of the blades 122. The coolant or lubricant may for example correspond to water. The spray nozzle assembly 134 is typically fluidly connected to a coolant or lubricant source via one or more hoses 136. The spray nozzle assembly generally includes a spray nozzle 138 for each cutting blade 122. The spray nozzle assembly 134 may be fixed to the spindle housing 132 so that the spray nozzles 138 can be positioned relative to the cutting blades 122, i.e., the spray nozzles 138 retain there position relative to the cutting blades 122. The spray nozzle assembly 134 may be attached to the spindle housing 132 via a fine tune positioning device 140 for allowing position adjustments, i.e., the position of the spray nozzles 138 can be adjusted relative to the blades 122.

The singulation subsystem 106 may include a pair of sawing devices 120, which may be operated independently or separately to dice the substrate 108. In one implementation, one of the sawing devices 120 is configured to cut the substrate 108 in a first direction (e.g., along the x axis) and the other sawing device 120 is configured to cut the substrate 108 in a second direction (e.g., along the y axis).

The singulation subsystem 106 also includes a chuck assembly 142 including a chuck 144 for holding one or more substrates and diced chips formed therefrom before, after and during dicing, and a stage 146 for moving the substrate 108 and the singulated chips to and from the sawing devices 120. The chuck stage 146 may also move the substrate during the singulation procedure in order to singulate the entire substrate. For example, the chuck stage may rotate 90 degrees in order to allow cuts in two directions (e.g., X and Y) and it may translate through the saw blades 122 so as to implement sawing. The chuck 144 may be widely varied. For example, the chuck 144 may be a mechanical, vacuum or electrostatic chuck (or the like). The vacuum chuck is arranged to apply suction to a smooth side of the substrate during and after singulation.

In one implementation, the chuck assembly 142 moves between an initial position where one or more new substrates 108 to be processed may be received and where the diced chips may be removed, and a singulation position where a singulation procedure may be performed. When the chuck assembly 142 is in the singulation position, the chuck assembly 142 is further configured to move so as to perform the singulation procedure (dice the one or more substrates 108 into a plurality of chips). For example, the chuck assembly 142 may translate towards the cutting blades 122 of the saw devices 120 in order to implement dicing. That is, the chuck assembly 142 moves along in the linear direction thereby feeding the substrates 108 into the array of saw blades 122 and effecting singulation (e.g., causing the blades 122 to cut through the substrates 108 that are held on the chuck 144). In one implementation, the chuck assembly 142 translates between a first position (e.g., singulation position) and a second position in order to move the substrates through the blades 122. Alternatively, the blades 122 may be translated in order to dice the substrates 108.

In addition, the chuck assembly 142 may rotate in order to allow cuts in multiple directions on the substrates 108. For example, the chuck assembly 142 may be configured to rotate between a first rotate position, placing the substrates 108 in a first cut direction, and a second rotate position, placing the substrate 108 in a second cut direction. In most cases, the first set of cuts is orthogonal to the second set of cuts (e.g., 90 degrees) so as to produce square or rectangular chips. Alternatively, the blades 122 may be rotated 90 degrees rather than the chuck assembly.

An exemplary process using the above arrangement may include 1) carrying one or more substrates from the initial to the cutting position via the chuck assembly, 2) making a first set of cuts on the substrates via a first saw while translating the chuck assembly, 3) carrying one or more substrates from the cutting position to the initial position via the chuck assembly, 4) rotating the substrates from the first rotation position to the second rotation position via a rotating chuck assembly, 5) carrying one or more substrates from the initial to the cutting position via the chuck assembly, 6) making a second set of cuts on the substrates via a second saw while translating the chuck assembly, 7) carrying the diced chips back to the initial position via the chuck assembly, and 8) rotating the diced chips back to the pre rotation position via the chuck assembly.

The chuck assembly 142 may be widely varied. For example, the chuck assembly 142 may include a single chuck 144 for holding a single substrate 108, or it may include a plurality of chucks 144 for holding a plurality of substrates 108. It is generally believed that increasing the number chucks 144 decreases the cycle time of the system, i.e., more substrate 108 may be diced for a given time. Each of the chucks 144 is arranged to hold an individual substrate 108. By having two chucks 144, two substrates 108 may be handled at the same time and thus the step of placing a second substrate 108 and removing the first substrate 108 may be removed. That is, two substrates 108 may be singulated while the chuck assembly 142 is translating (e.g., in the cutting position) thereby decreasing the handling time associated with handling one substrate 108 at a time. For example, the time it takes to translate and rotate the chuck assembly 142 as well as the time it takes to receive and remove the substrate 108 and chips to and from the chuck assembly 142.

In one particular embodiment, the chucks 144 are configured to receive the nest 112 and provide a vacuum in order to hold the substrate 108 and diced chips before, after and during dicing. In this embodiment, each of the chucks 144 includes a vacuum retainer plate 148 and vacuum pedestals 150. The substrate 108 is placed, into the nest 112 which is then mounted on the vacuum retainer plate for dicing. By mounting the nest 112 on the vacuum retainer plate 148, vacuum pedestals 150 on the vacuum retainer plate 148 protrude through the nest 112 to raise the substrate 108 above the upper surface of the nest 112. The top surface of the vacuum pedestal 150 also forms a vacuum seal with the smooth undersurface of the die to be cut, allowing the die to be held securely to the top surface of the vacuum pedestal 150 when the vacuum is turned on. Because the substrate 108 is raised slightly above the top surface of the nest 112, the die saw may protrude below the thickness of the substrate 108 without risking damage to either the nest 112 or the saw blade 122.

During cutting, the saw blades 122 are disposed within channels which are present between vacuum pedestals 150 in the vacuum retainer plate 148. The recessed channels may be sized to permit some degree of fluctuation in side to side placement of the saw blades 122. Increasing the width of the channels will decrease the top surface area of each vacuum pedestal 150, but that will not significantly impact the ability of the vacuum to hold the cut die on top of the vacuum pedestal 150.

In some cases, after the substrate 108 is cut, a top cover (not shown) is placed over the nest 112 containing the cut dies of the substrate 108. The top cover typically has contact posts which hold down each individual die. This combination of the top cover, the nest 112 and the cut dies in between forms a covered nest fixture, which is then lifted off the chuck 144. By lifting the covered nest fixture from the chuck 144, the individual dies are permitted to drop back down to the nest surface. More specifically, each nest opening has retainer walls disposed adjacent to its opening. When each cut die drops down to rest on the top surface of the nest 112, the retainer walls securely hold each cut die by their edges, thereby preventing the translational and rotational motion of the cut die. The cut dies, being held substantially immobile by the retainer walls, as well as trapped between the contact posts of the top cover and the nest 112, may now be further processed (e.g., washing, rinsing, drying) while being kept substantially immobile. Since each cut die is held substantially immobile

on the surface of the nest by the retainer walls, the diced chips are essentially aligned and ready to be removed from the nest 112 when the top plate is removed, as for example, using a pick and place machine. In this manner, the overall dicing process is automated and the cut dies are held immobile during cutting, transporting, and subsequent processing without the use of tape as well as aligned for subsequent picking and placing.

The substrate processing system may also include post singulation subsystems 152 where the singulated chips are further processed. The post singulation subsystems 152 may be widely varied. For example, the post singulation subsystems 152 may include buffer stations 154, cleaning stations 156 (wash and dry), positioning stations 158, inspection stations 160and/or the like, as well as transfer mechanisms for moving the chips through the various stations. Buffer stations 154 generally relate to areas used to store the chips between two different processings thereof. For example, a buffer station may be used to store chips after singulation, but before cleaning. Cleaning stations 156 generally related to areas used to wash and dry the chips. As should be appreciated, particles or debris may adhere to the singulated chips and thus they need to be cleaned. Positioning stations 158 generally relate to areas used to reposition the chips, as for example, for grouping chips together, for separating them or for moving them to a desired location. Inspection stations 160 generally relate to areas used for inspecting the substrate or chips. By way of example, a visual inspection using a camera may be employed.

A cutting sequence will now be discussed. The sequence generally begins by placing a substrate on a nest. By way of example, the substrate may include leadless integrated circuit packages 352 such as QFN packages. Once secured to the nest, the nest is moved to the chuck for placement thereon. During placement of the nest, the substrate is positioned on the surface of the vacuum pedestal, i.e., the vacuum pedestal extends through and above the nest thereby lifting the substrate off the nest. After placement of the nest, the vacuum is turned on, and the substrate is held in place by a suction force. The suction force is generated through the openings in the vacuum pedestal.

Once the substrate is fixed by the suction force, the substrate moves from a load/offload position to a cutting position via the stage. Thereafter, a first saw is lowered into a cutting position. That is, a robot moves the first saw device in the z direction until the blades reach a desired cutting height, which is generally very close to the substrate. The cutting blades are then rotated at a desired cutting speed. When rotating, the spray nozzle begins to spray coolant and/or lubricant on the blades. The cutting blades begin to make a first set of linear cuts on the substrate when the chuck is translated in the cutting direction via the stage. The chuck may make one pass and then step in order to make another pass through the cutting blades until all the first set of linear cuts are made.

After completing the first set of linear cuts, cutting blades and spray nozzle are turned off and the second saw is raised. Thereafter, the chuck is moved back to the load/unload position, where the chuck is rotated 90 degrees via the stage. After rotation, the chuck is moved back to the cutting position via the stage. Thereafter, a second saw is lowered into a cutting position. That is, a robot moves the second saw device in the z direction until the blades reach a desired cutting height, which is generally very close to the substrate. The cutting blades are then rotated at a desired cutting speed. When rotating, the spray nozzle begins to spray coolant and/or lubricant on the blades. The cutting blades begin to make a second set of linear cuts on the substrate when the chuck is translated in the cutting direction via the stage. The chuck may make one pass and then step in order to make another pass through the cutting blades until all the second set of linear cuts are made. After completing the second set of linear cuts, the chuck moves back to the load/unload position where the substrate is offloaded along with the nest for the next processing task.

Figs. 4A and 4B are perspective diagrams of the pin-less nest assembly 200, in accordance with one embodiment of the present invention. The pin-less nest assembly 200 is generally located in an area for prepping a single substrate for dicing, i.e., pre-singulation (104 in Fig. 3). The pin-less nest assembly 200 generally includes a pin holder plate 202 and a nest 204. Fig. 3A shows the nest 204 separated from the pin holder plate 202 and Fig. 3B shows the nest 204 mounted on the pin holder plate 202. The pin holder plate 202 is located within the prepping area while the nest is movable therefrom, i.e., used to transfer the substrate 206 and dies cut therefrom to

various stations including singulation. The nest 204 is configured, or otherwise arranged, to translationally and rotationally reduce the movement of a substrate 206 and packages cut therefrom positioned within nest 204. When a substrate 206 is properly positioned with respect to nest 204, the substrate 206 rests against a grid arrangement 208. Grid arrangement 208 defines openings 210, which accommodate the packages cut from the substrate 206. That is, the packages of the substrate 206 are at least partially placed within openings 210. In most cases, the nest openings 210 are arranged to accommodate packages, which have a footprint, which is of substantially the same shape as nest openings 210. The number of openings 210 may be widely varied, but generally correspond to the number of packages located on the substrate 206. Each opening effectively "holds" one package.

To elaborate, the nest openings 210 are formed through the thickness of nest 204. The size of each nest opening 210 is dimensioned to be slightly smaller than the dimension of the cut die to prevent the cut die from falling through. Each nest opening210 is typically surrounded at its opening by retainer walls (not shown), which are disposed on top surface of nest 204. Retainer walls are arranged such that a cut die can rest on top surface of nest 204 while overlying nest opening 210, yet have its edges retained within retainer wall to limit the translational and rotational movement of the individual cut die.

The nest 204 is configured to mate with several plates including but not limited to the pin holder plate 202 (shown) and a vacuum retainer plate (not shown). The nest 204 includes pilot locator holes 212, which may be used to align the nest 204 against the pin holder plate 202 and the vacuum retainer plate. The pilot locator holes 212 receive locator posts 214 disposed on the pin holder plate 202 and vacuum retainer plate. The nest 204 also includes one or more through holes 216 for receiving locator pins 218, which are employed to align the substrate 206 to the nest 204. The locator pins 218 are positioned on the pin holder plate 202 and extend through the through holes 216. That is, when the nest 204 is mated with the pin holder plate 202, the locator pins 218 extend above the top surface of the nest 204. The alignment or locator pins 218 extending above the surface of the nest 204 are used to engage locator holes 220 on a substrate 206 in order to position the substrate 206 with respect to nest 204.

To elaborate, the locator pins 218 include a base 222 dimensioned for sliding receipt within the through holes 216 of the nest 202 and a tapered section 224 for sliding receipt within the locator holes 220 on the substrate 206. The locator pins 218 are typically press fit into voids in a base plate 202. Geographically speaking, the position of the locator pins 218 and locator through holes 216 generally correspond to the position of the locator holes 220 on the substrate 206. By removing the locator pins 218 from the nest 204, the locator pins 218 do not interfere with the cutting blades or other features of the sawing devices during the cutting sequence.

Once the substrate 206 is aligned with the nest 204, a cover (not shown) may be used to secure the substrate 206 to the nest 204 in order to maintain its proper position relative to the nest 204. The cover stays locked with the nest 204 during substrate transfer. The cover is removed when the nest 204 is positioned on the vacuum retainer plate and the vacuum is turned on thereby securing the substrate 206 to a vacuum chuck (vacuum pedestals). The cover may for example include a pad including locator pins or holes for engaging corresponding pins and holes in the nest and/or the substrate. The pad also typically includes a mating surface for engaging the substrate, i.e., the mating surface is pressed against the substrate to hold the substrate against the nest.

Another aspect of the invention relates to the design of a nozzle for directing fluid over the cutting blades of a dicing machine. The cutting blades employed to dice packaged lead-frame strips generate heat and a substantial quantity of particulates as unwanted byproducts of the cutting process. Currently, nozzles are employed to direct water or some other fluid onto the blades. This fluid flow acts to cool the blades, as well as to lubricate them so as to facilitate the cutting process. The fluid flow also acts to clean particulates from the blades and lead-frame strips. Because additional fluid flow acts to further cool, lubricate, and clean the blades and lead-frame, ongoing efforts are being made to further improve the flow rate and flow characteristics of nozzles.

Current nozzles simply direct a stream of fluid at the edge of cutting blades, a configuration that often fails to adequately cool, clean, and lubricate the sides of the

blades. Thus, Fig. 5A illustrates a nozzle assembly 310 with a pipe member 312 and a nozzle member 314. Fluid flows through the pipe member 312 in the direction of the arrow shown, where it is directed into the nozzle member 314 and out through a plurality of channels 316.

Figs. 5B-5C illustrate isometric and side views, respectively, of a dicing assembly employing the nozzle of Fig. 5A. As described above, one or more cutting blades 318 are affixed to a rotating spindle 320 with spacers 311. The cutting blades 318 are then placed partially within the channels 316 of the nozzle member 314. In operation, the spindle 320 is spun to rotate the cutting blades 318, which then act to dice a lead-frame strip. When the cutting blades 318 are rotating, fluid is forced through the pipe member 312 and through the channels 316 of the nozzle member 314. As the nozzle member 314 partially surrounds the blade 318, fluid is forced along both the edges of the blades 318, as well as at least part of the sides. In this manner, more fluid contacts the blades 318 than with conventional nozzles. This results in improved cooling of the blades 318, as well as better removal of particulate matter and better lubrication.

Figs. 5D-5G illustrate various views of the nozzle member 314, so as to explain its operation in further detail. The nozzle member 314 includes a plurality of channels 316 that are each sized and shaped to accommodate a cutting blade 318. More specifically, each channel 316 has a width 322 sufficient to enclose a blade 318 within, and a depth 324 sufficient to direct fluid along the sides of the blade 318. Additionally, the channels 316 are spaced a distance 326 apart from each other, corresponding to the distance between blades 318, or the width of a die. Angle 328 is also cut out of the nozzle 314, so as to keep the nozzle 314 from impinging upon the spacer 311.

The nozzle member 314 can be fabricated from a stainless steel, but the invention contemplates the construction of nozzle members 314 made of any material compatible with the pipe member 312 and capable of withstanding the dicing environment. In embodiments in which the nozzle 314 and pipe 312 are made of metal, the channels 316 can simply be cut through the body of the nozzle 314, and the back end 330 is simply welded to a corresponding opening of the pipe 312. It should be noted that the invention is not limited to the nozzle 314 configuration described in

Figs. 5D-5G. Rather, Figs. 5D-5G simply illustrate one embodiment of the invention, which simply discloses a nozzle shaped and sized to direct a flow of fluid onto both the edges and the sides of cutting blades 318.

Fig. 5H illustrates further details of the nozzle 314 in operation. As described above, cutting blades 318 are placed within the channels 316 so that the nozzle 314 partially surrounds the cutting blade 318. Fluid is then directed through the channel 316 and onto the cutting blade 318. When the blade 318 spins to cut a lead-frame 338, heat is generated and particulate matter is produced. The fluid acts to lubricate the blade 318, and remove both the generated heat and particulate matter from the edges and sides of the blade 318. In order to more effectively direct fluid onto the blade 318, the nozzle 314 is configured so that its channels 316 surround the blade 318 while satisfying the various spatial constraints of the dicing process. For instance, the angle 328 is designed so as to allow a clearance 334 between the nozzle 314 and spacer 311. This prevents the nozzle 314 from touching the spacer 311, and also allows space for fluid to flow out of the channel 316 onto the blade 318. Similarly, the nozzle 314 is designed with a clearance 336 so as to prevent it from scraping against lead-frames 338 during dicing. The clearance 336 and/or the width of the nozzle 314 also keep the nozzle 314 from contacting any locating pins 332 that are commonly used to locate the lead-frames 338 during dicing. Fig. 5I illustrates a view orthogonal to that of Fig. 5H, in which it can be seen that the locating pins 332 provide yet another design constraint. Specifically, as the locating pins 332 are often placed between blades 318, the nozzles 314 are designed with cutouts 332 that prevent contact with the pins 332 during dicing. One of skill will realize that the invention contemplates a nozzle 314 designed with any dimensions and configurations that satisfy these space constraints.

Referring back to Figs. 5D-5G, the nozzle 314 will be described in accordance with one embodiment. As mentioned, the nozzle 314 includes a plurality of channels 316, each of which form a separate spray nozzle 350, i.e., they each force fluid over a separate cutting blade. The channels 316 are contained within two portions of the nozzle 314: a blade receiving portion 352 and a fluid passage portion 354. The channels of the fluid passage portion 354 are configured to direct fluid from the pipe member 312 to the channels of the blade receiving portion 352. These channels may

for example be through holes, openings or slots. The channels of the fluid passage portion 354 generally include an inlet 356 for receiving the fluid from the pipe 312 and an outlet 358 for distributing the fluid to the channels of the blade recieing portion 352. The channels of the blade receiving portion 352 are configured to direct fluid not only at the edge of the cutting blade but also its sides. The channels of the blade receiving portion 352 are formed by several walls including side walls 360 and a bottom wall 362. The side walls360 and bottom wall 362 are configured to surround the blade thus helping to force fluid around the cutting blade, i.e., keeps the fluid in greater contact with the cutting blade (time, area, etc.). Fluid that would normally be deflected away is redirected over the blade. A greater volume of fluid can therefore be used to flush the blade.

It should be noted that this particular arrangement is not a limitation and that it may vary according to the specific needs of each blade. By way of example, the channel in the blade receiving portion 352 may correspond to a cut out thus eleimnating the bottom wall 362. Furthermore, the fluid passage portion 354 may include a resouvoir in between the channel inlets 356 and the pipe 312.

Ine one embodiment, the cross sectional area of the channels in the fluid passage portion is greater than the holes in conventional spray nozzles. This allows a greater volume of fluid to be distributed to the blades. The flow rate canbe increased. As should be appreciated, more fluid typically increases both cooling and lubrication.

An additional aspect of the invention involves the composition of the fluid used during dicing. As described above, a fluid is pumped through the pipe 312 and channels 316 of a nozzle 314, so as to cool, clean, and lubricate the blade 318. This fluid can be simply water. However, the presence of certain additional compounds acts to enhance the desired properties of the fluid. Thus, the invention contemplates the addition of any compounds that act to enhance the cooling, lubricating, or particulate removal capabilities of fluid used in dicing. For example, the addition of known soap or other cleaning solutions acts to improve both the lubricating and cleaning abilities of the fluid. The addition of lubricants such as those manufactured by Mirachem™ or Castrol™ also acts to improve lubrication. The invention

therefore contemplates the addition of these and any other compounds that modify the properties of fluid so as to improve the dicing process.

Another aspect of the invention involves finely positioning the spray nozzles relative to the cutting blades. Figs. 6A-C are a diagrams of a nozzle adjustment assembly 400, in accordance with one embodiment of the present invention. Figs. 6A and B are different perspective views of an assembled nozzle adjustment assembly 400 while Fig. 6C is an exploded perspective view showing the parts that make up the nozzle adjustment assembly 400. The nozzle adjustment assembly 400 is configured to adjust the position of the spray nozzle assembly relative to the cutting blades. The adjustment is typically performed before a cutting sequence (set-up).

The nozzle adjustment assembly 400 includes a spindle bracket 402. Although not shown, the spindle bracket 402 is typically attached to the spindle assembly as for example the spindle housing. The spindle bracket 402 is configured to set the coarse position of the spray nozzle assembly relative to the cutting blades.

The nozzle adjustment assembly 400 also includes a nozzle bracket 404 for supporting a spray nozzle assembly as for example the assembly shown in Fig. 5. The nozzle bracket 404 is configured to pass a fluid (coolant and/or lubricant) between an inlet and an outlet. The inlet generally includes an inlet coupling 406 for receiving a hose from a fluid source and an outlet coupling 408 for receiving the end of the nozzle adjustment assembly. Both the inlet and the outlet couplings 406 and 408 are attached to a bracket body 410. The bracket body 410 includes a fluid passage 412 from the inlet to the outlet. The fluid passage 412 is configured to direct thefluid from the inlet to the outlet. The bracket body 410 also provides a structure for attaching to the spindle bracket 402.

In one embodiment, the nozzle bracket 404 and more particularly the bracket body 410 is movably coupled to the spindle bracket 402 so that the spray nozzle position relative to the cutting blade position can be finely adjusted. In most cases, the nozzle bracket 404 moves linearly relative to the spindle bracket 402. The nozzle bracket 404 can be made to move along a single axis or multiple axis. For example, the nozzle bracket 404 may be configured to only move along the y axis or it may be

configured to move along two axis (x and y), all three axis (x, y and z). It may also be configured to rotate about the x, y and z axis.

In the illustrated embodiment, the nozzle bracket 404 and more particularly the bracket body 410 is configured to translate relative to the spindle bracket 402. The direction of translation is parallel to the axis of the spindle and cutting blades (e.g., y axis). By allowing translation in this direction, the spray nozzle assembly can be more precisely placed relative to the cutting edge of the cutting blades. That is, the spray nozzle assembly can be linearly moved so as to properly place the spray nozzles as close as possible to the centerlines of each of the cutting blades.

To elaborate, the nozzle bracket 404 is movably coupled to the spindle bracket 402 via a fine tune translation mechanism 414. The fine tune translation mechanism 414 is configured to convert rotary motion to linear motion. The fine tune translation mechanism 414 includes a travel housing 416, an adjustment housing 418 and a fine tune knob 420. The travel housing 416 is slidably coupled to the spindle bracket 402. This may be accomplished via a travel groove 422 located on the travel housing 416 and a slider 424 located on the spindle bracket 402. The travel groove 422 mates with slider 424 in order to produce the sliding motion. The slider 424 and groove 422 are typically designed in such a way as to keep the travel housing 416 retained to the spindle bracket 402. For example, the slider 424 and travel groove 422 may include tapered or sloped portions to slidably retain the travel housing 416 to the spindle bracket 402.

The travel housing 416 includes an attachment structure 426 to which the nozzle bracket 404 is attached. In most cases, the nozzle bracket 404 is attached to the travel housing 416 with one or more screws or bolts 428. The nozzle bracket 404 may include a slot 430 so that the Z position of the nozzle bracket 404 can be adjusted relative to the travel housing 416 and thus the spindle bracket 402. For example, the screws can be loosened so as to allow the nozzle bracket 404 to slide relative to the travel housing 416 via the slot 430. Once the desired height is found, the screws 428 can be tightened to maintain this height.

The adjustment housing 418 is attached to the spindle bracket 402 via one or more screws or bolts 432. The adjustment housing 418 is configured to rotatably support the fine tube knob 420. That is, the fine tune knob 420 is configured to rotate relative to the adjustment housing 418. The rotation is provided by a fine tune knob 420 that includes a shaft 434 that is inserted in an opening 436 in the adjustment housing 418. The shaft 434 includes a collar 438 that is trapped in a void between a mounting plate 440 and the adjustment housing 418. The collar 438 maintains the knob 420 position relative to the adjustment housing 418 (the mounting plate and adjustment housing serve as y direction abutment stops to the shaft). The shaft 434 also includes a threaded portion 442 at its end that is threadably coupled to a threaded receptacle 444 within the travel housing 416. When the fine tune knob 420 is rotated, the engaged threads pull or push the travel housing 416 along the groove/slider interface. That is, the threaded portion 442 travels into or out of threaded receptacle 44 (depending on the direction of knob rotation) thereby causing linear motion of the travel housing 416. Because the nozzle bracket 404 is attached to the travel housing 416, it to moves linearly along the y axis.

The nozzle bracket 404 may include an angle adjustment elbow 450. The angle adjustment elbow 450 is configured to rotate about the y axis so that the angle of the spray nozzle assembly can be adjusted. This may be needed for deep cuts. The angle adjustment elbow 450 is fluidly and rotatably coupled to the bracket body 410 via an adjustable fitting 452 and typically includes a passage that extends to the outlet coupling 408. The position of the angle adjustment elbow may be set by using a friction coupling or some other fastening means such as a screw or bolt.

A further aspect of the invention relates to the design of spacers that separate cutting blades. As discussed above, packaged lead-frame strips are often diced, or singulated into individual packages, by employing rotating cutting blades. Commonly, one or more blades having circular cross-sections are placed on a spindle, which is then spun to cut the lead-frame strip into individual dice. When more than one blade is employed, in a configuration commonly referred to as a gang cutter, each blade is placed on the spindle and separated by a spacer, which helps maintain a specified gap between blades (often, the width of each singulated die).

Prior art spacers are, however, not without their drawbacks. More specifically, current spacers often contain gaps that allow fluids used in the dicing process to collect within the spindle assembly. The weight of this added fluid contributes to spindle imbalance, leading to vibration and inferior cutting.

Fig. 7A illustrates a prior art spacer 510 that allows for such fluid accumulation. As shown in Fig. 7A, spacers 510 are simply annular members having raised surfaces 512 extending from secondary surfaces 514, as well as an inner radius 516 and outer radius 518. As can be seen in the successively more detailed Figs. 7B-7C, which illustrate cross-section AA of Fig. 7A, spacers 510 are placed with their inner radii 516 against a spindle, and used to separate cutting blades 520. However, when spacers 510 are placed against the cutting blades 520, the spacers 510 only contact the blades 520 along their raised surfaces 512, thus leaving a gap 522. During dicing, fluid used in the dicing process tends to accumulate in this gap 522, thus creating imbalance problems when the blades 520 are spun.

Fig. 8A illustrates a spacer 610 constructed in accordance with an embodiment of the present invention so as to reduce this fluid accumulation problem. A spacer 610 is formed with surfaces 612 that are flat, without raised surfaces. As illustrated in the successively more detailed Figs. 8B-8C, which illustrate cross-section AA of Fig. 8A, spacers 610 do not have raised surfaces such as surfaces 512 of Fig. 7A. As a result, when the spacers 610 are placed against cutting blades 520, their surfaces 612 lie substantially flush against the cutting blades 520, with no gap such as gap 522 to collect fluid. Thus, the spacer 610 essentially eliminates the raised surfaces 512, removing any gap 522 where fluid may collect.

To ensure adequate contact with the blades 520, the surfaces 612 can be fabricated to at least the same degree of flatness and surface finish as the raised surfaces 512 of prior art spacers. For example, many prior art spacers 510 have raised surfaces 512 that are ground to a flatness of $\pm 2\ \mu m$, and a Grade 8 surface finish. Accordingly, spacers 610 can have surfaces 612 that are ground to at least the same flatness and surface finish, although the invention contemplates surfaces 612 ground to any flatness and surface finish that ensures adequate contact with the cutting blade, and prevents any substantial accumulation of fluid.

Fig. 9 illustrates an arbor and spacer assembly.

Figs. 10A-10C illustrate one embodiment of a nozzle assembly

A method using the above principles will now be discussed. The method generally comprises a set-up procedure including: 1) generating a nest, pin holder plate, vacuum retainer plate, spacers and spray nozzle assembly corresponding to the appropriate package array; 2) coupling the cutting blades to an arbor using the spacers; 3) coupling the arbor to the saw; 4) coupling the spray nozzle assembly to the saw, 5) adjusting the spray nozzle position relative to the cutting blades; and 6) assembling the nest, pin holder plate, and vacuum retainer plate inside a substrate processing machine. The method also includes a cutting process that is performed on the substrate processing machine, the method including: 7) placing the nest on the pin holder plate; 8) loading and aligning a substrate on the nest; 9) placing a cover over the substrate in the nest; 10) placing the substrate and nest on the vacuum retainer plate; 11) turn on the vacuum at the vacuum retainer plate to secure the substrate; 12) remove cover from nest; 13) move vacuum retainer plate and thus the nest and substrate to cutting area; 14) turn on saw thereby causing cutting blades to rotate; 15) turn on spray nozzle to lubricate and cool each of the cutting blades; 16) cut substrate into a plurality of dies; 17) place cover on cut dies and nest while vacuum is still turned on; 18) move vacuum retainer plate and thus the nest and cut dies to buffer area.

While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and equivalents, which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

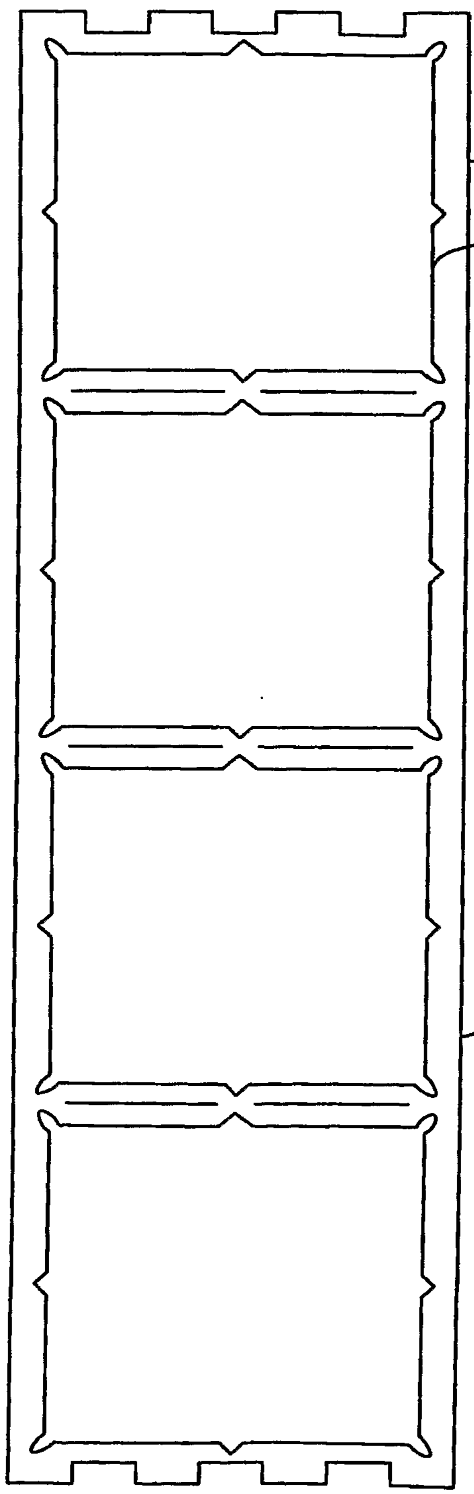


FIG. 1A

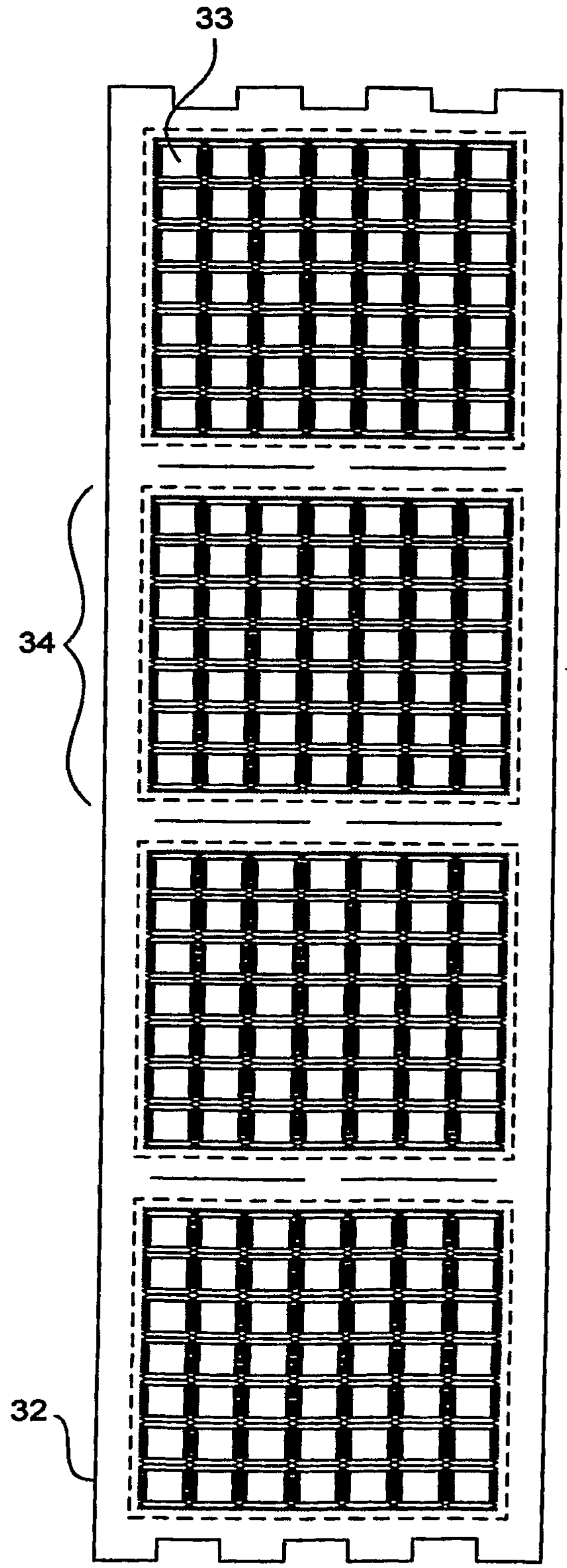


FIG. 1B

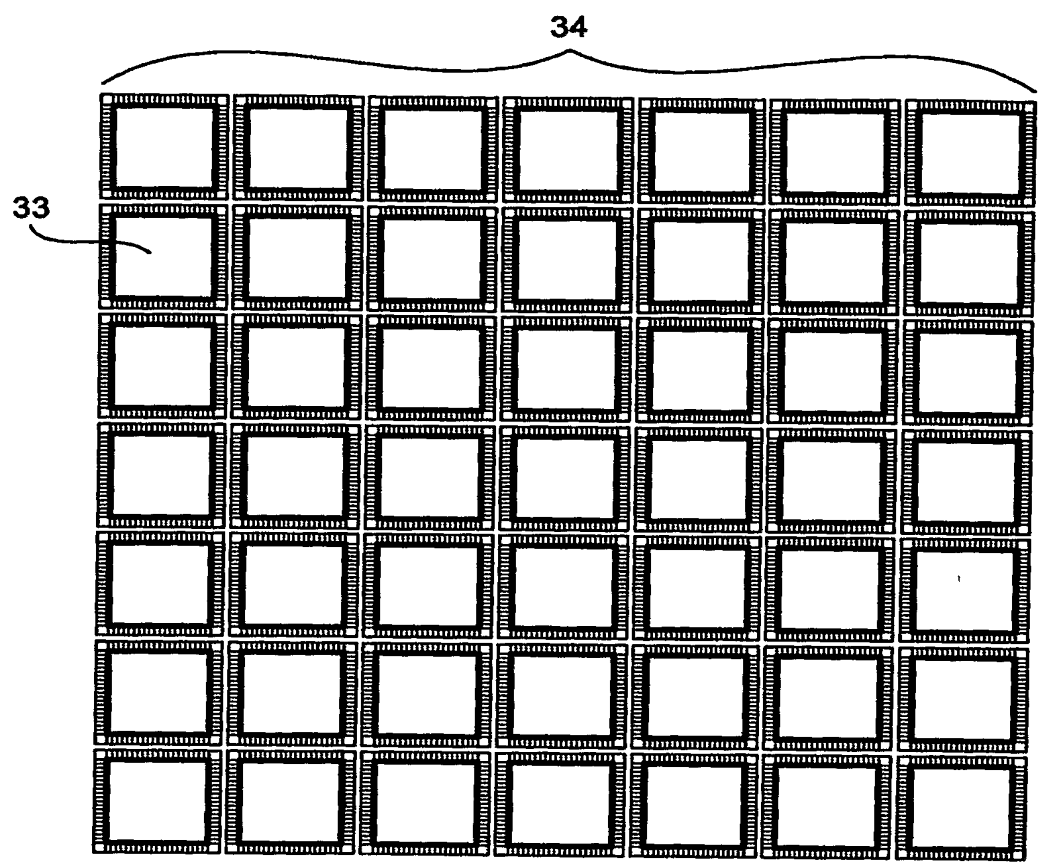


FIG. 1C

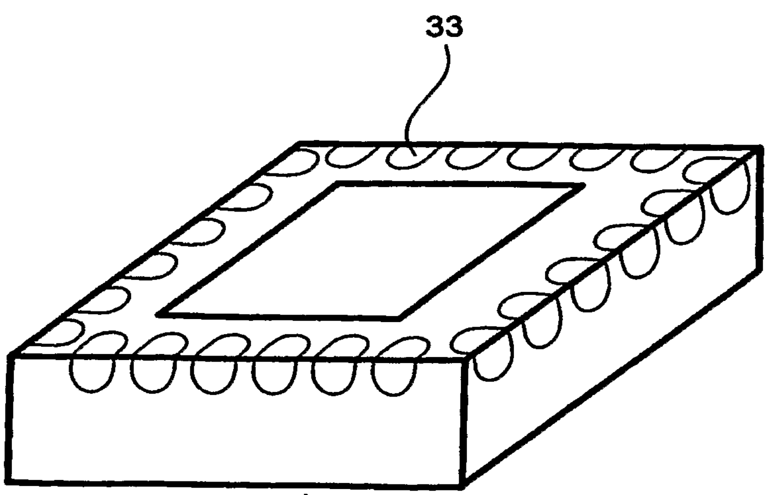


FIG. 1E

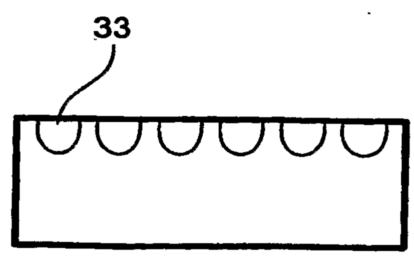
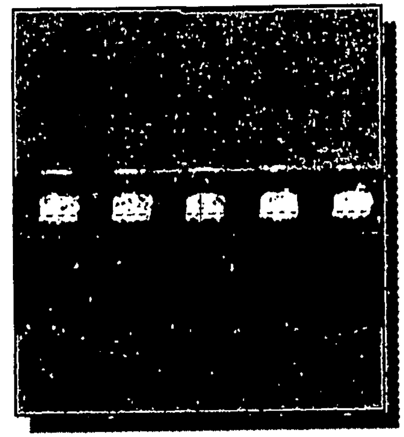


FIG. 1D

- QFN dicing process consists of two main types of material:

✓ **Half etched copper**:



An average of 50% of Intercon's qfn customers use the half etched process. Currently there is no process for gang for qfn with more than 2 blades. All machine features are standard per industry.

✓ **Full copper:**

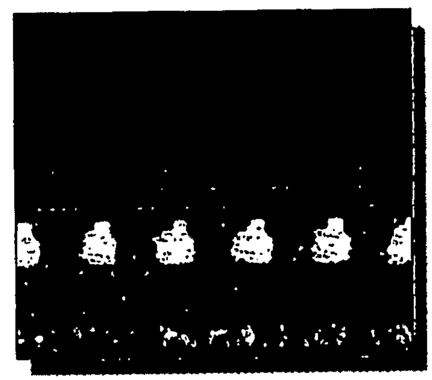


FIG. 2A

Standard Process

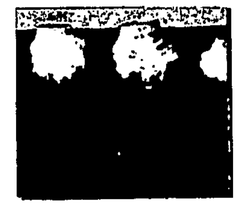
- **Machine:**
  - Most commonly used machine is the EAD 695 singulation engine from Disco.
- **Blades:**
  - Blades come in most cases in 3" diameter, average of 300 microns, 78 mm OD.
- **Method:**
  - Platform process for qfn cutting is:
    - ✓ Single blade
    - ✓ 20 k rpm
    - ✓ 10 mm sec (full copper, single blade)
    - ✓ 80 mm/sec (half etched, single blade)
    - ✓ 30 mm/sec (half etched, two blade gang)
- **Standard results:**
  - Average blade life: 300 to 600 meters for full copper
  - Average throughput: 6000 to 8000 units/hour (max. 12000 units per hour – PSC)

FIG. 2B

Limitations of process

❖ Due to the properties of copper the following issues commonly occur during dicing: of QFN

- ✓ Blade loading/ blade breaking
- ✓ Cut quality failures
- ✓ Part movement
- ✓ Low feed speed
- ✓ Short blade life
- ✓ Low throughput



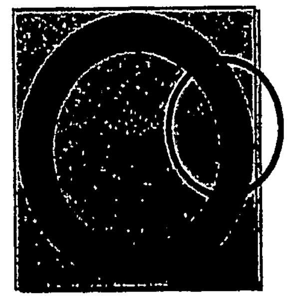


FIG. 2C

Initial tests and findings

In order to optimize the qfn process Intercon has made the following modifications:

Emulsion system (closed loop)

Modified gang nozzle

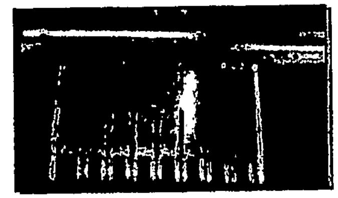


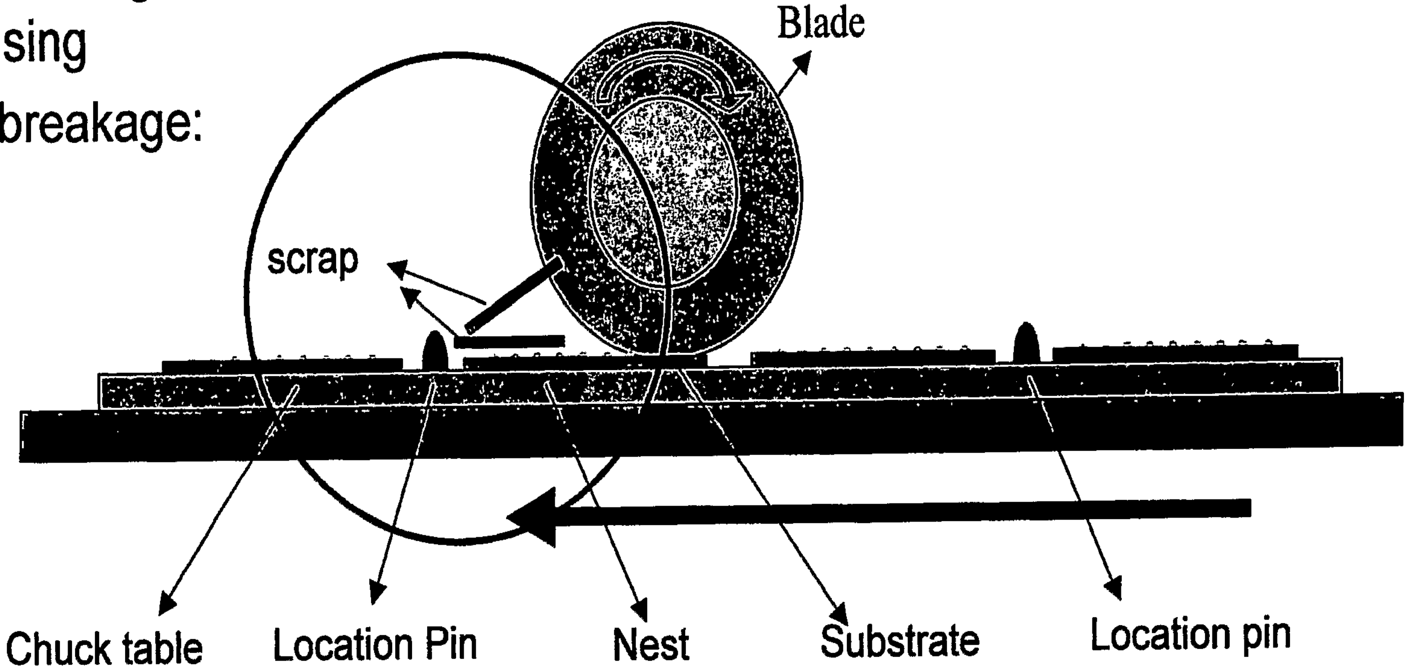
FIG. 2D

The purpose of these changes was to reduce blade wear while maintaining the good cut quality with the gang assembly.

Results and added modifications

Due to the high number of blades, scrap and debris impacted the gang causing

Blade breakage:



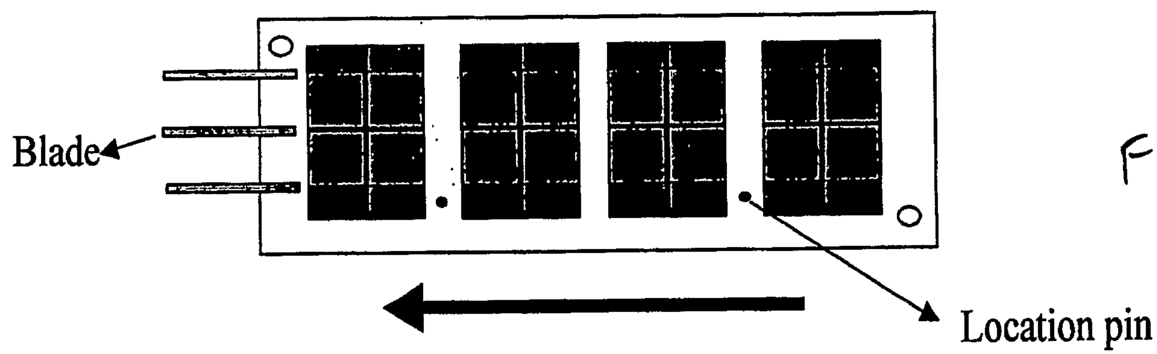
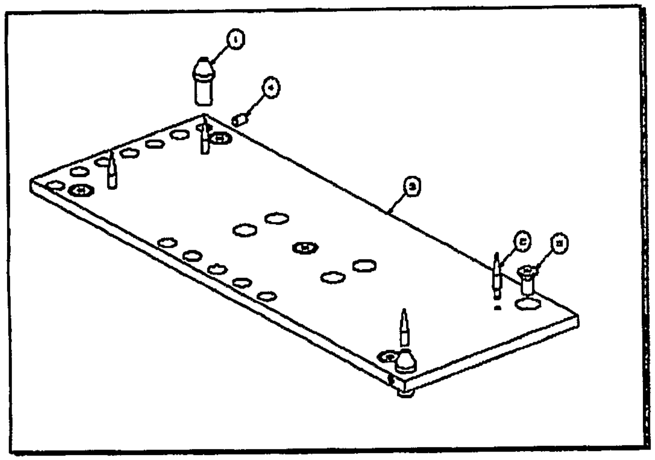
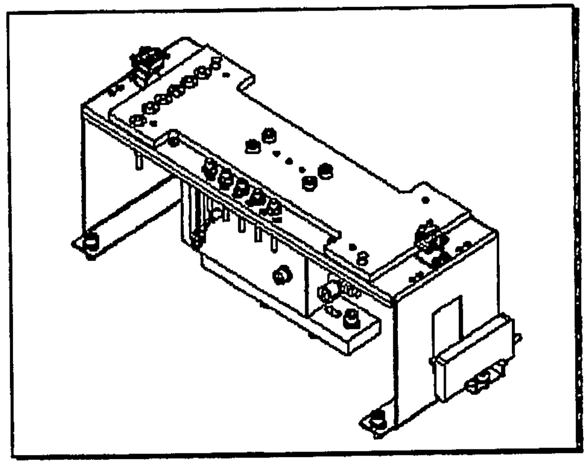


FIG. 2E

To avoid further blade breakage, Intercon recommended the 'prestage alignment feature' also known as ' nestless pin' feature.





As a result of this change, the pinless nest will allow the scrap to flow freely without impeding the blade, or the cut path. By this change, the scrap motion is controllled by water flow and cleared off the nest.

FIG. 2F

Further developments

As testing continued, additional issues have surfaced in the cutting process:

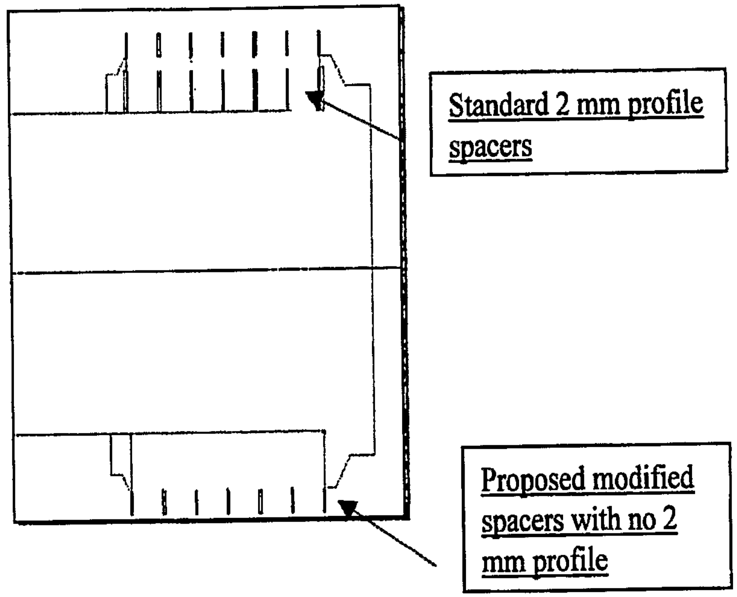
- Balanced weight of gang changes during cutting due to the nr of blades and added water weight
- Due to the type of nozzle, fine adjustment of nozzle position became necessary to maintain blade centrality and position control.

Solutions proposed by Intercon:

- Modify spacers to eliminate raised profile in order to reduce the amount of water weighting down the gang assembly.
- Modify the bracket for the gang blades to enable fine adjustment by adding threaded position locking nuts.

FIG. 2G

1. Spacers changed:



2. Nozzle bracket changes:

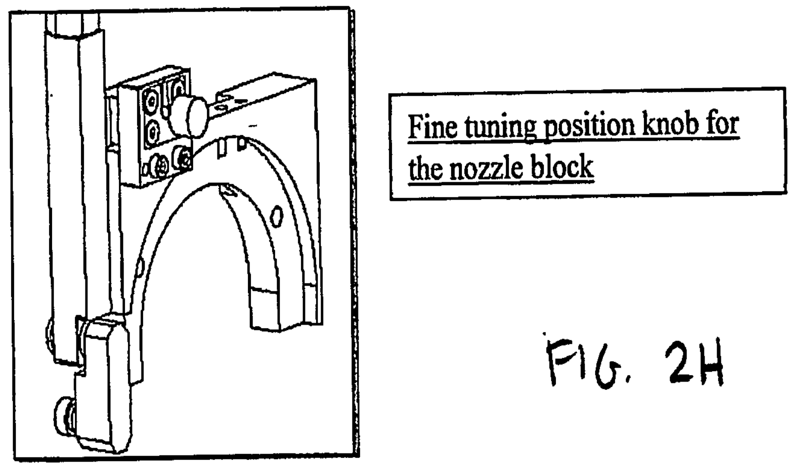


FIG. 2H

Summary of changes for optimizing the qfn gang process

The qfn dicing process can be stabilized in a production environment by implementation of all of the following changes:

1. Emulsion system (kerf aid, Mirachem, Castrol, etc). – **better blade life**
2. Modified nozzle. – **more cooling for blades**
3. Prestage alignment (pinless nest). – **no scrap caused breakage**
4. Spacers changes. – **no added weight by water load inside spacer**
5. Bracket changes – **fine adjust position of multi blade gang**

These process, hardware and mechanical changes, yield new non precedented results for qfn: 19 000 UPH, 35 seconds cutting time, 7 & 9 blades gang, theoretical blade life of over 1000 meters.

FIG. 21

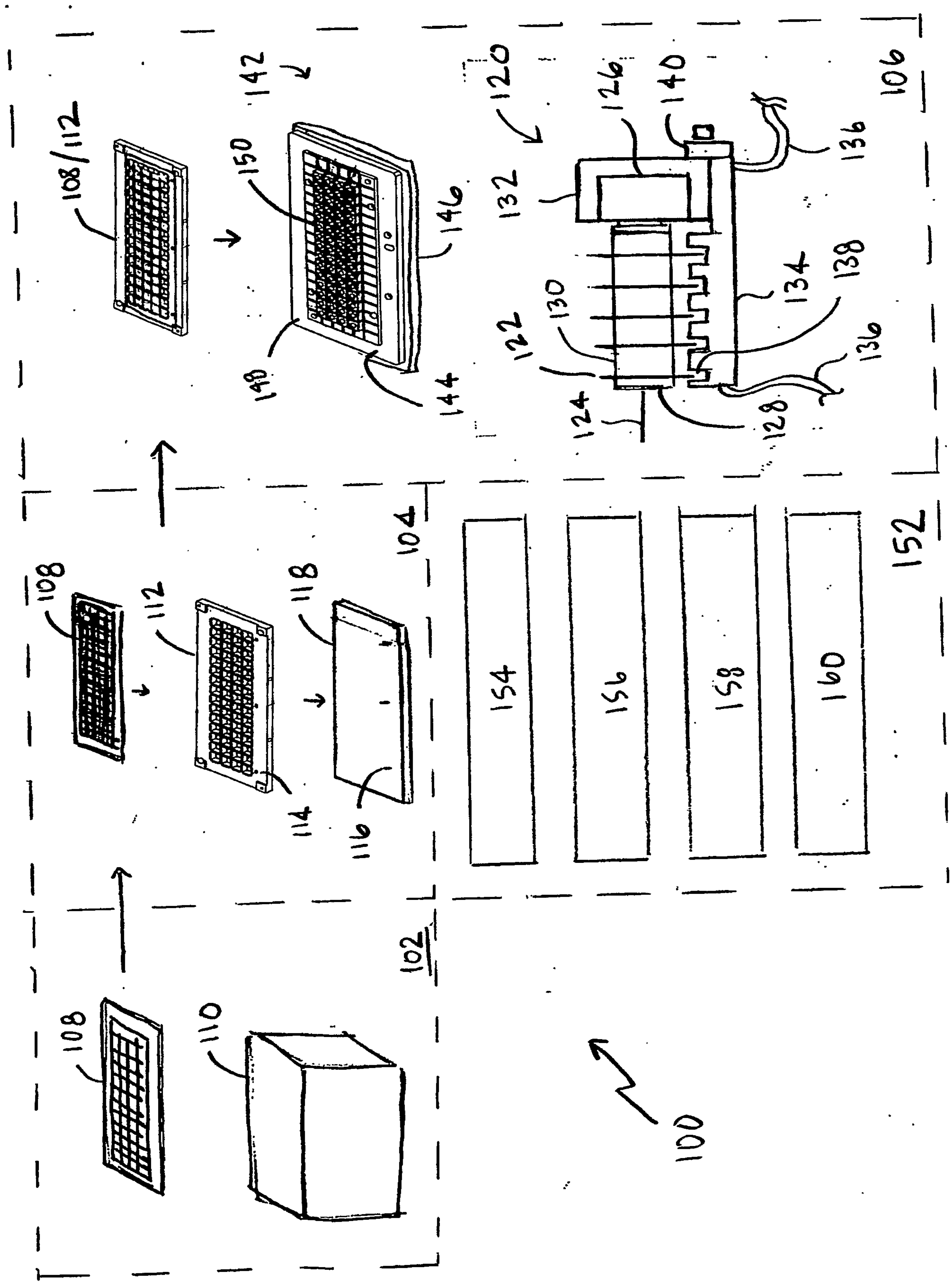

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FIG. 3

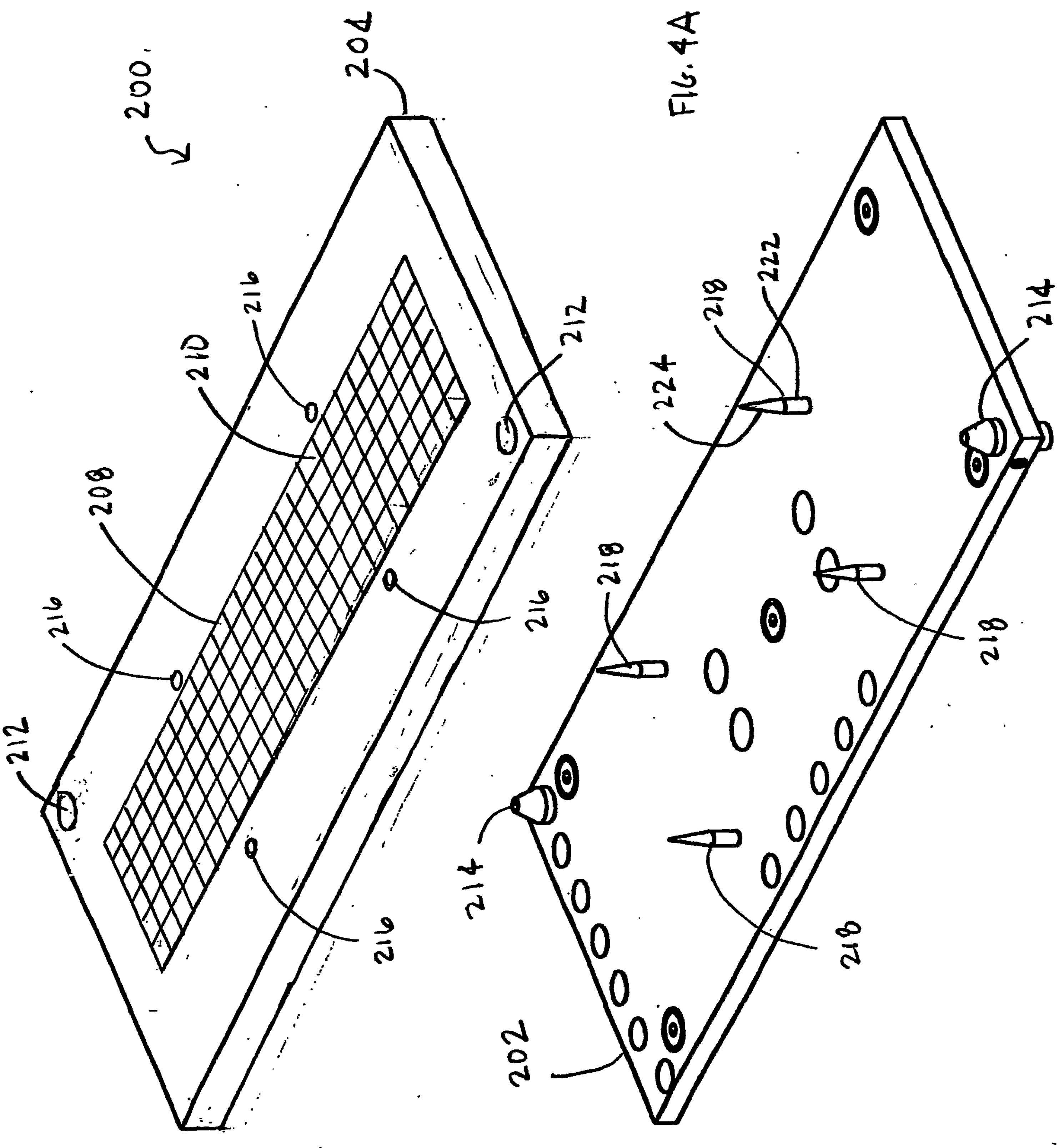
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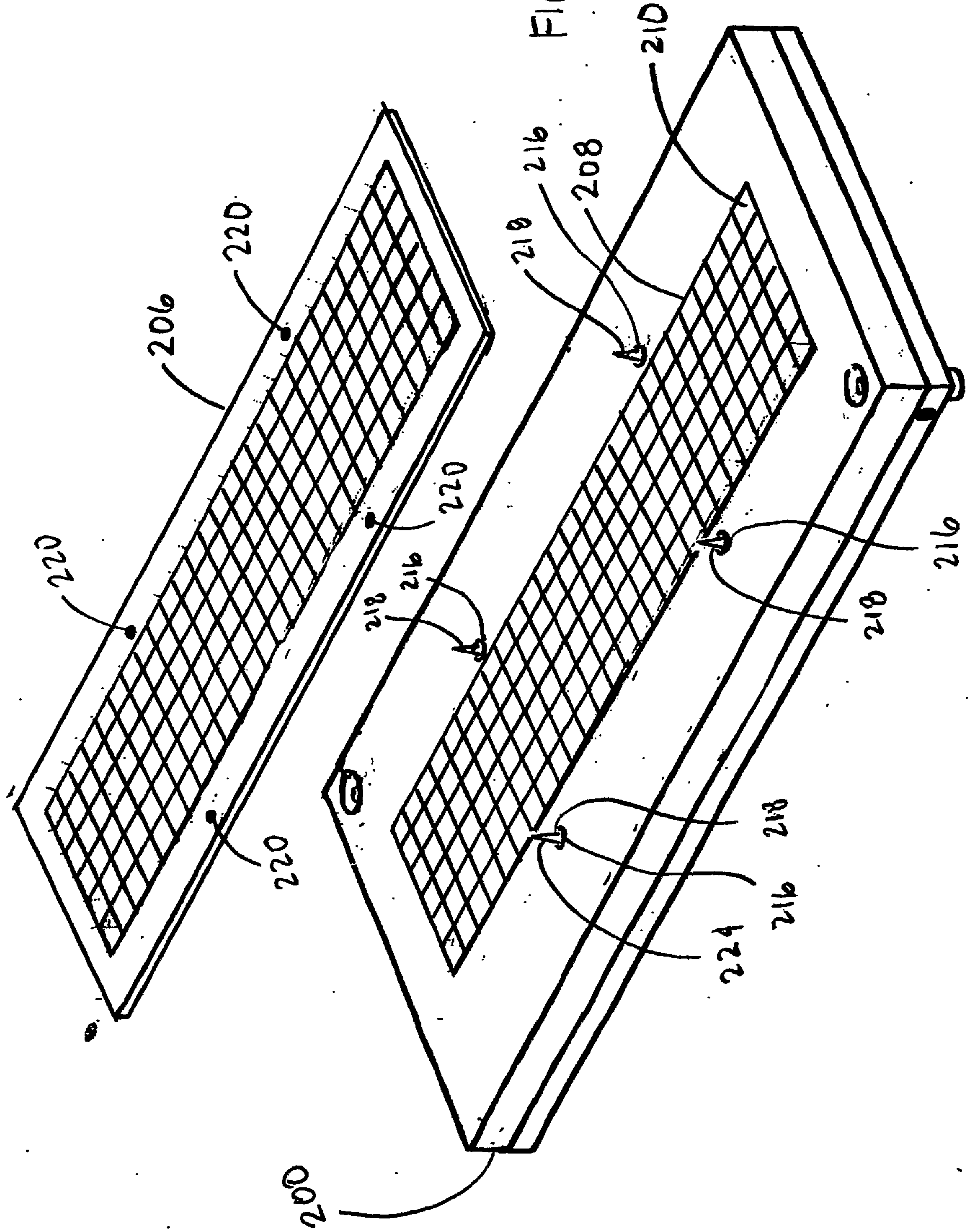
FIG. 4A

FIG. 4B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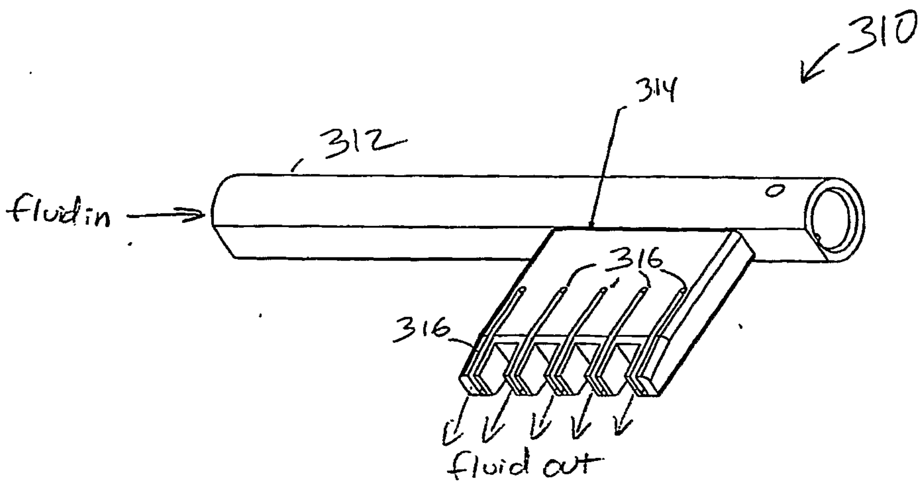


Fig. 5A

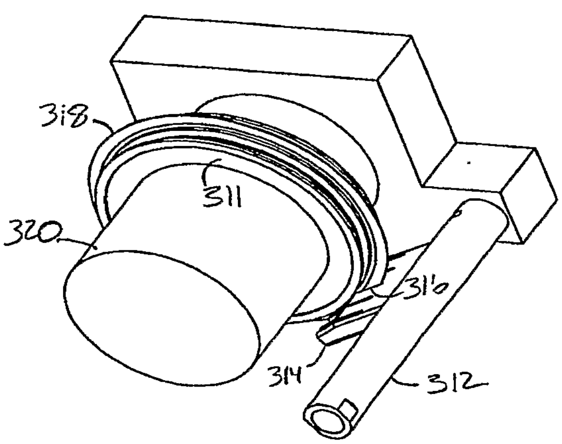


Fig. 5B

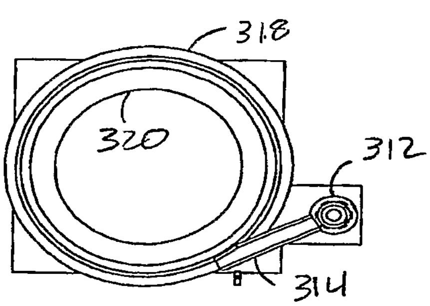


Fig. 5C

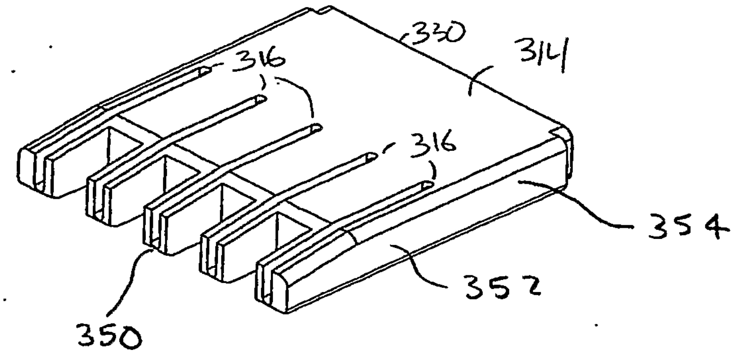


Fig. 5D

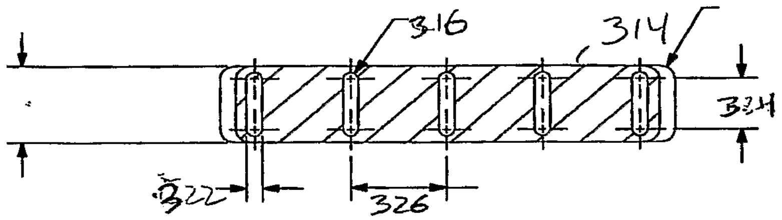


Fig. 5E

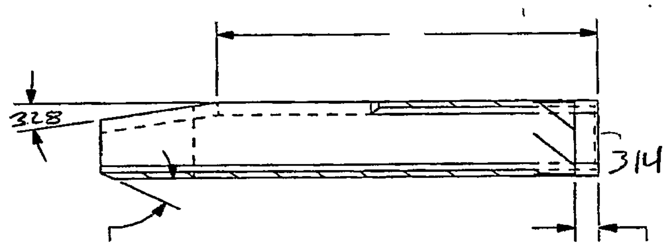


Fig. 5F

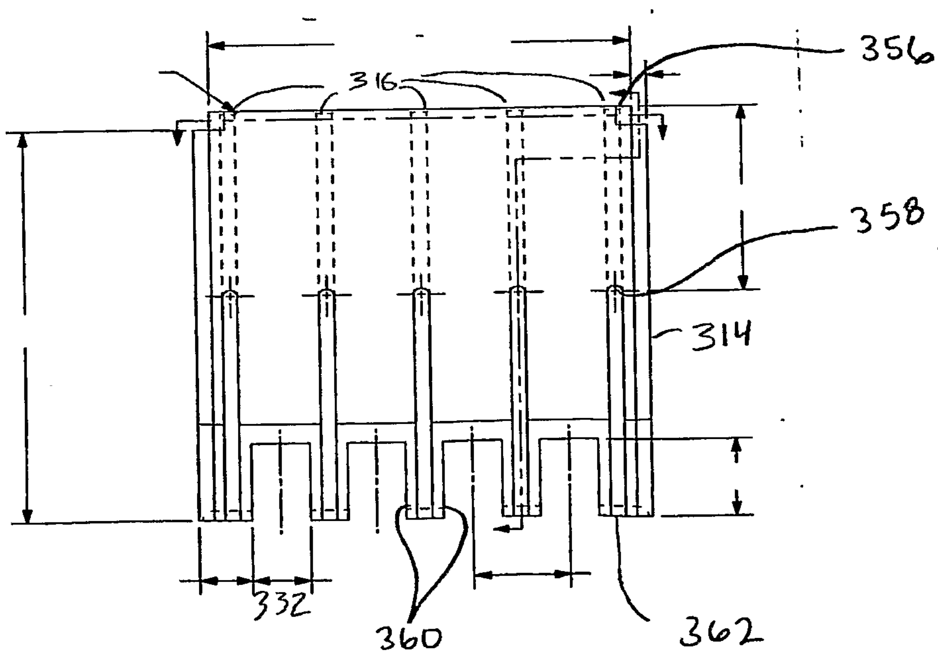


Fig. 5G

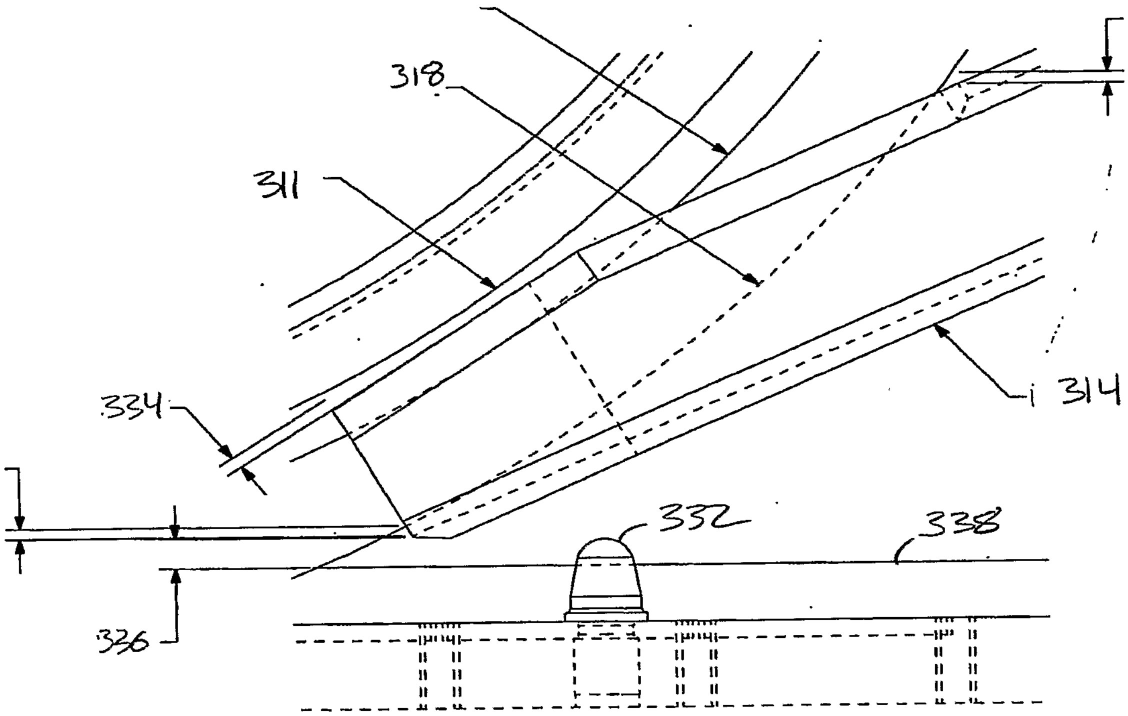


Fig. 5H

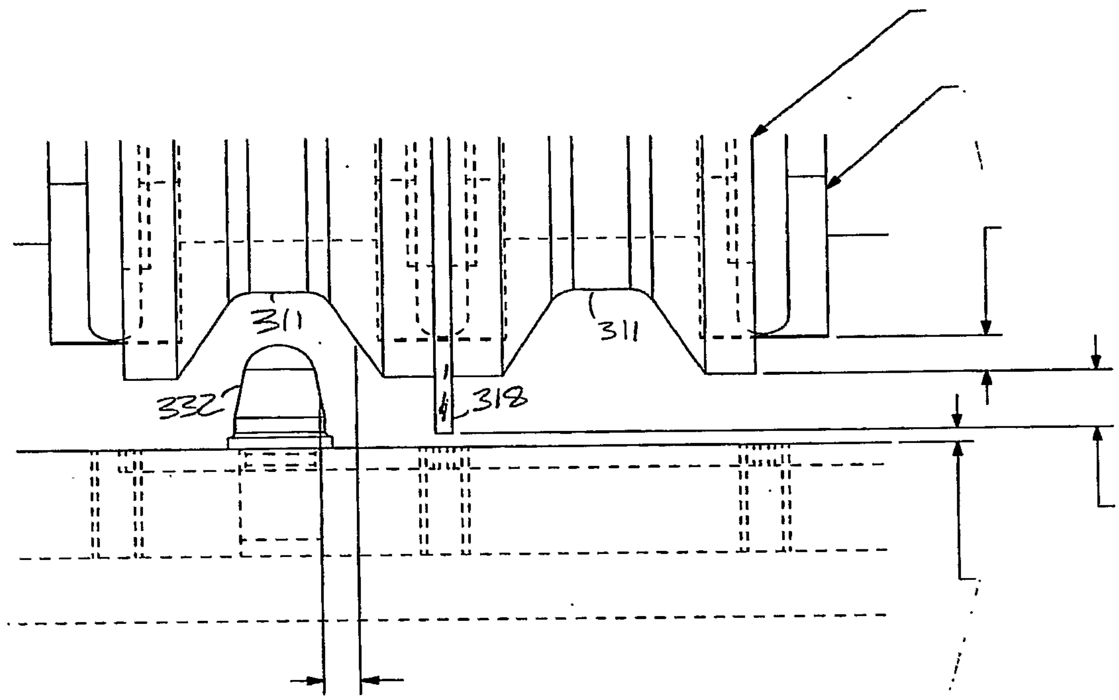


Fig. 5I

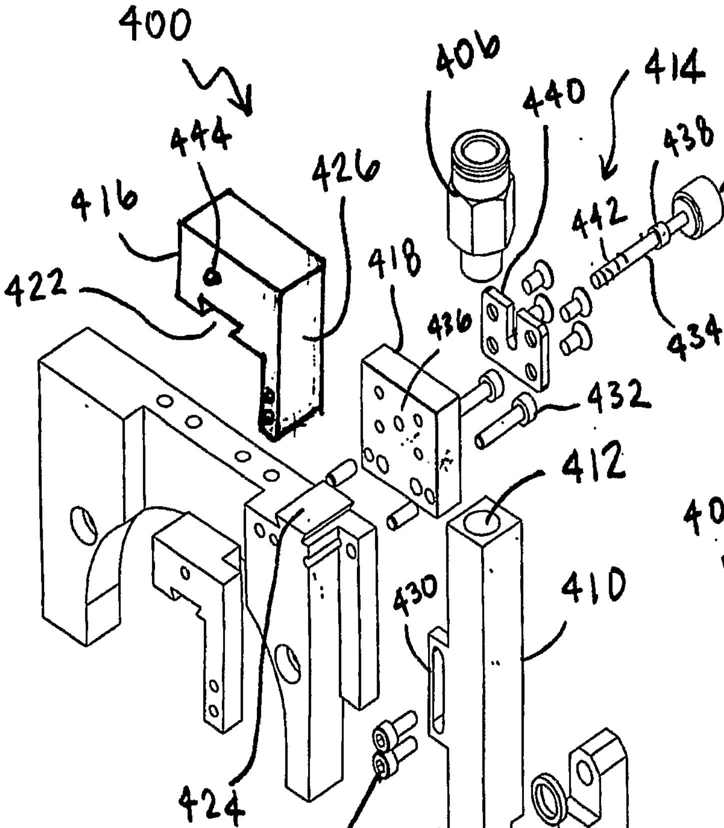


FIG. 6C

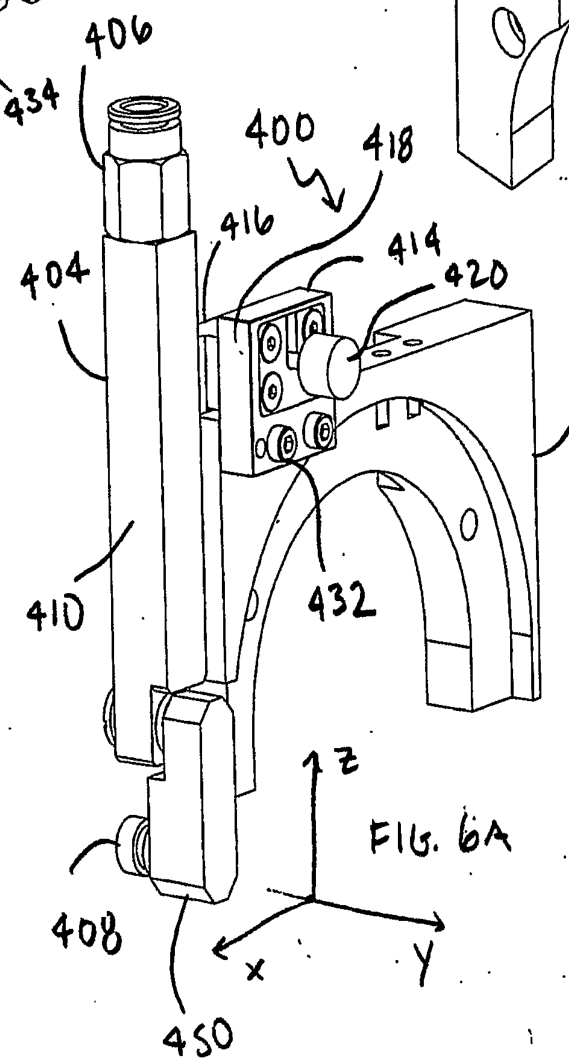


FIG. 6A

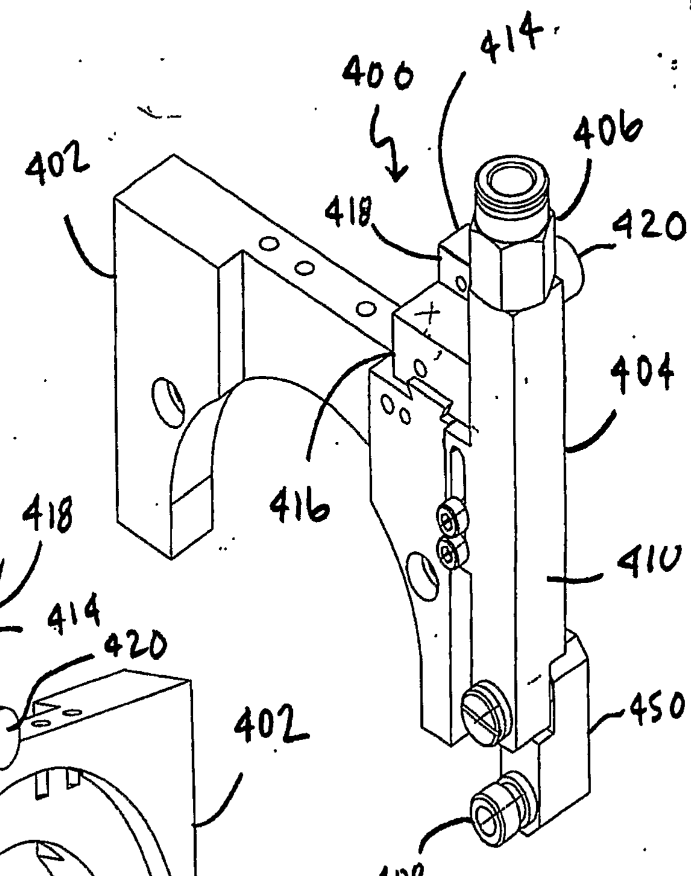


FIG. 6B

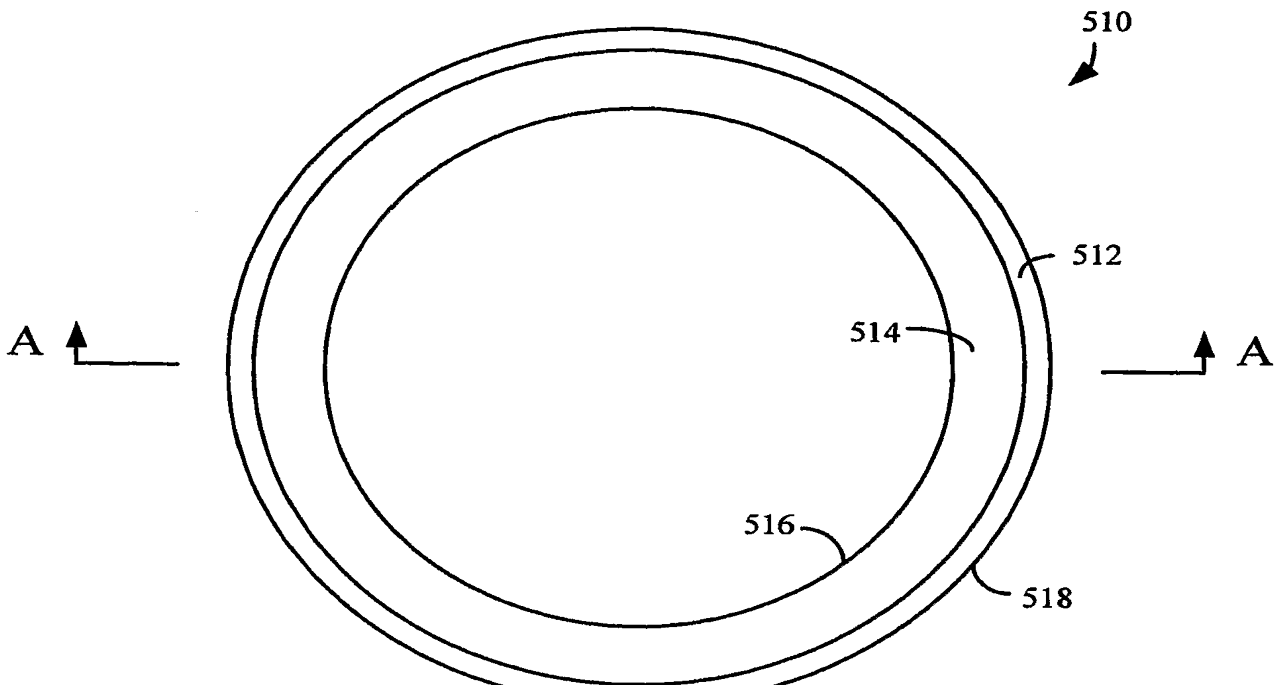


FIG. 7A
(Prior Art)

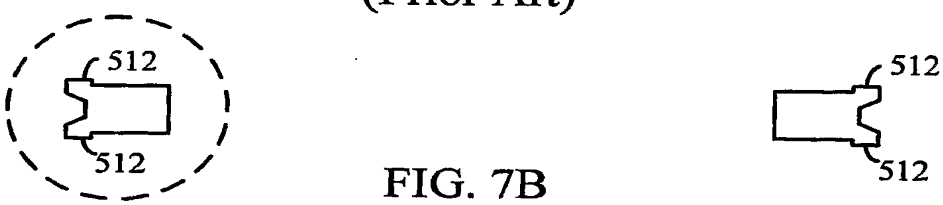


FIG. 7B
(Prior Art)

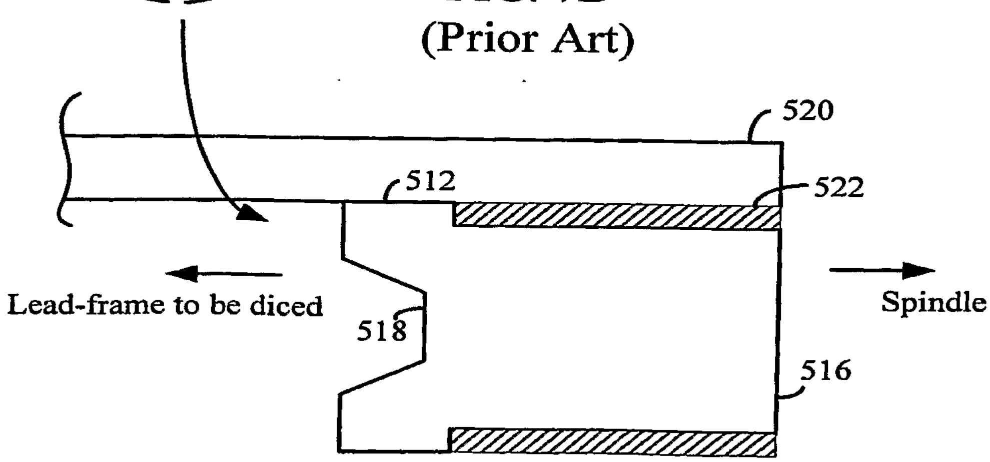


FIG. 7C
(Prior Art)

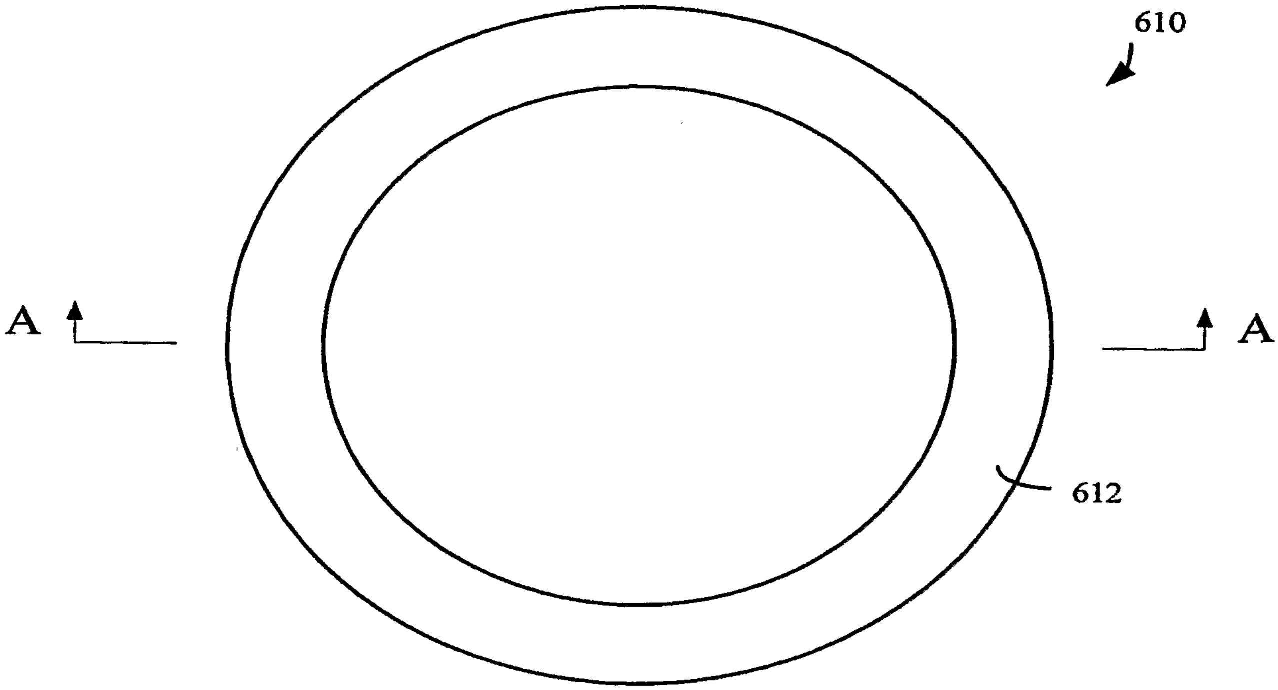


FIG. 8A

FIG. 8B

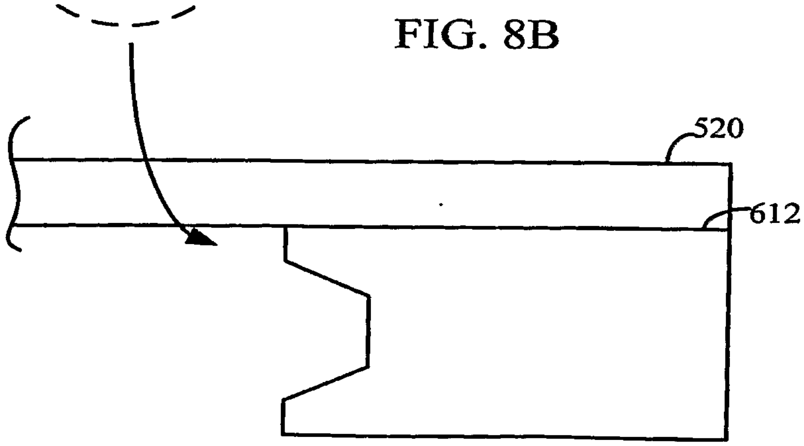


FIG. 8C

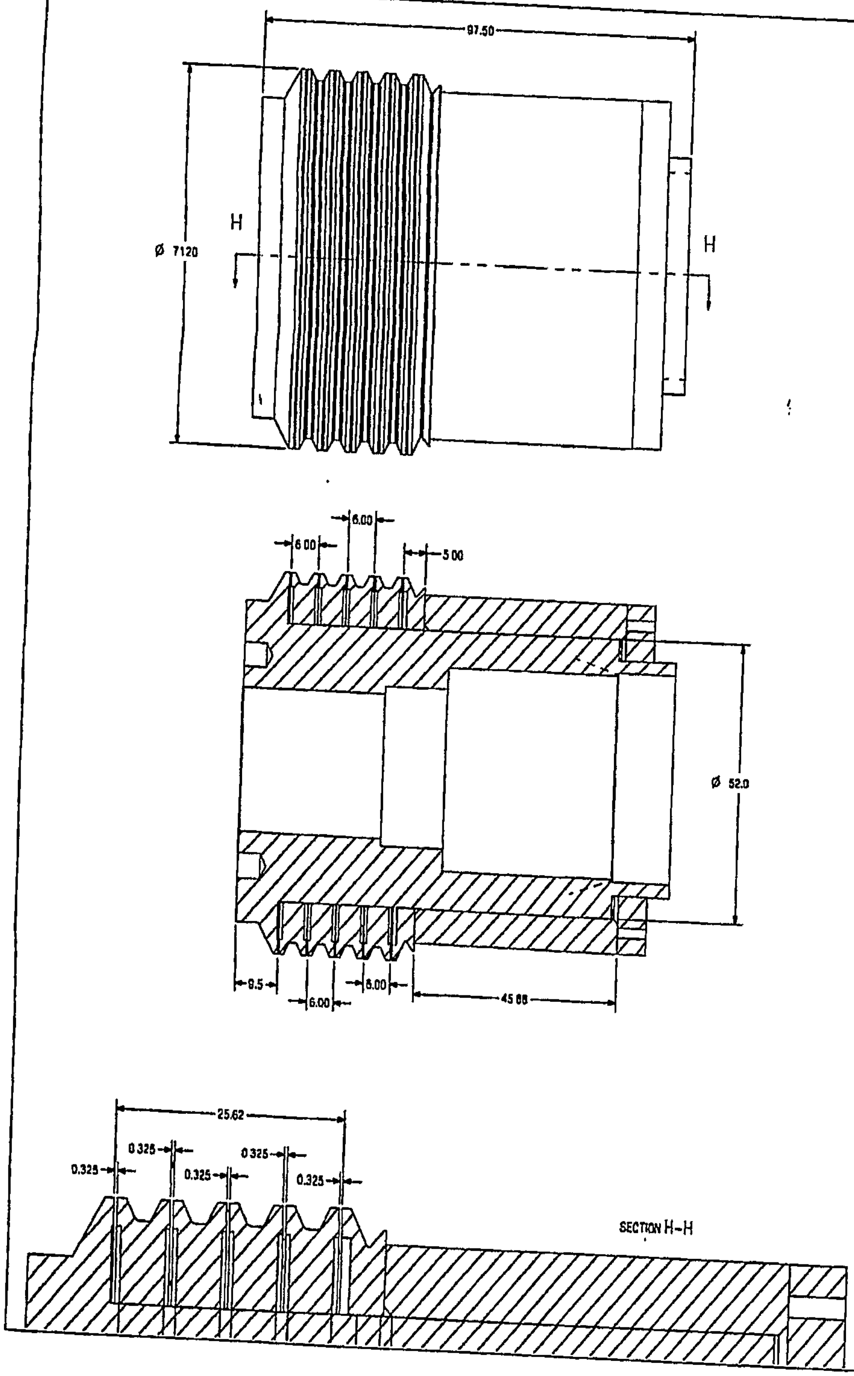
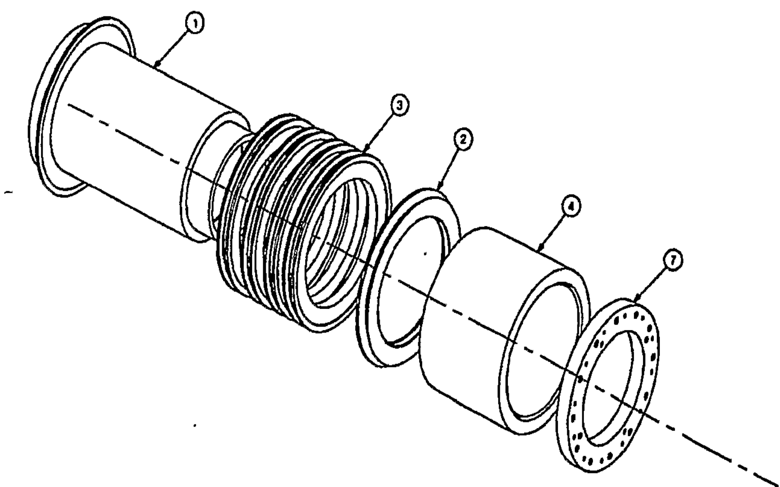


FIG. 9



RECMD SPARE	M/P	ITEM	DESCRIPTION	MFG DESC.	MATERIAL/ VENDOR
-	MFG.	7	LOCKNUT, ARBOR For 695 SAW	SEE DETAIL	AL6081
	MFG	6	NOZZLE, WATER 6x6 OFN Z1	SEE DETAIL	303 STAINLESS STL
-	MFG	5	TIP, WATER NOZZLE	SEE DETAIL	303 STAINLESS STL
-	MFG	4	HUB FILLER 45.88mm (695 SAW)	SEE DETAIL	AL 6081
-	MFG	3	HUB SPACER 6mm (695 SAW)	SEE DETAIL	TITANIUM 64 ALLOY
-	MFG	2	ENDCAP, ARBOR For 695 SAW	SEE DETAIL	TITANIUM 64 ALLOY
-	MFG	1	ARBOR For 695 SAW	SEE DETAIL	TITANIUM 64 ALLOY

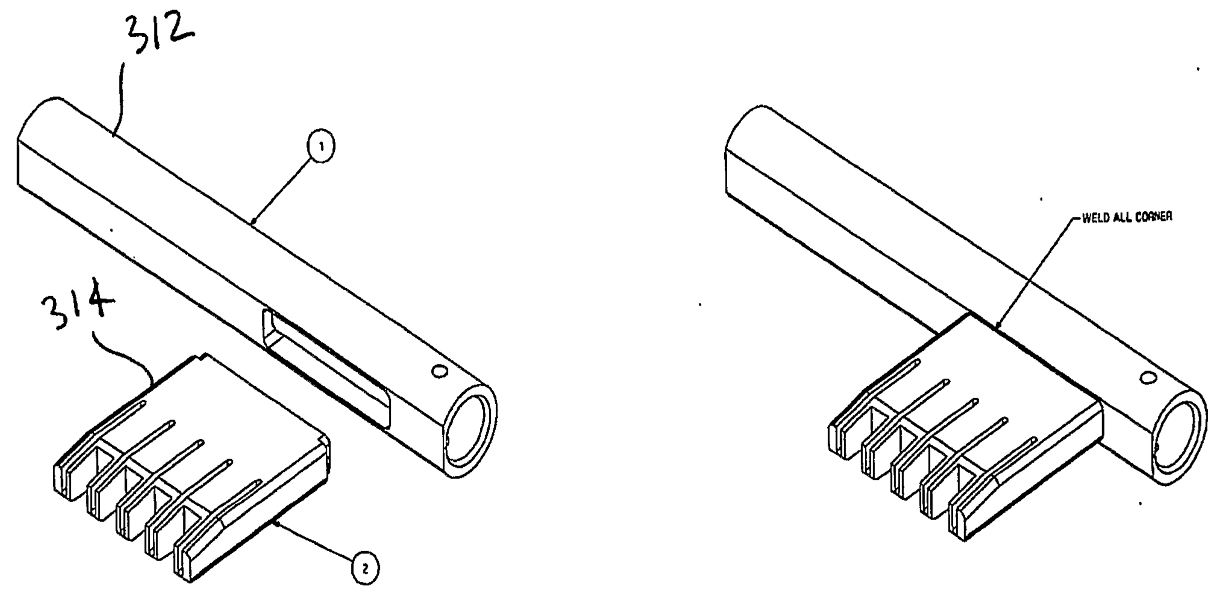
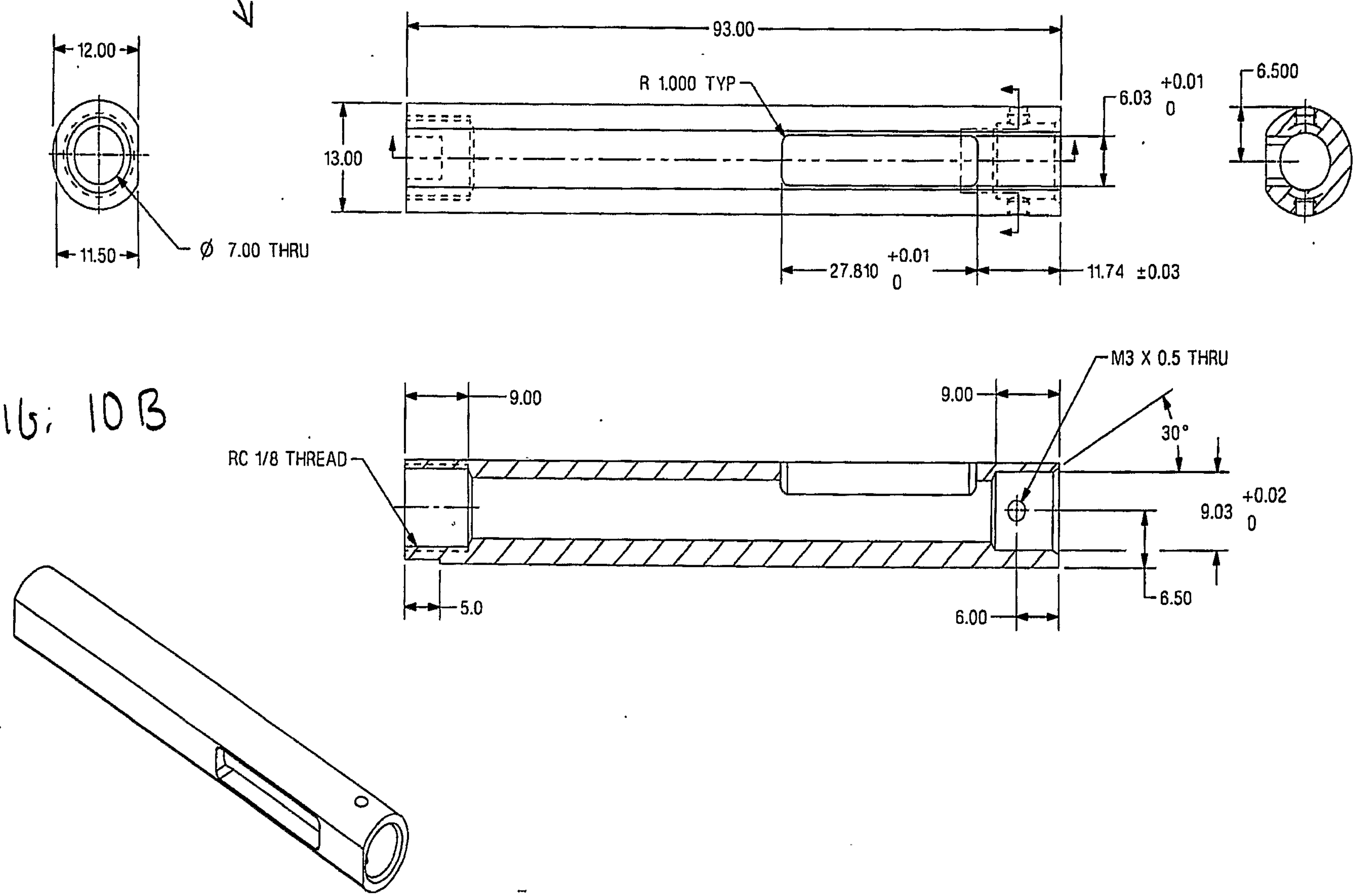


FIG. 10A

RECMD SPARE	M/P	ITEM
-	-	2
-	-	1

DESCRIPTION	MFG DESC.	MATERIAL/ VENDOR
BLOCK, NOZZLE TIP	SEE DETAIL	303 STAINLESS
NOZZLE, WATER	SEE DETAIL	303 STAINLESS

312



12.00
11.50
Ø 7.00 THRU
93.00
R 1.000 TYP
13.00
6.03 +0.01 0
6.500
27.810 +0.01 0
11.74 ±0.03
M3 X 0.5 THRU
9.00
9.00
30°
RC 1/8 THREAD
9.03 +0.02 0
5.0
6.00
6.50

FIG. 10B

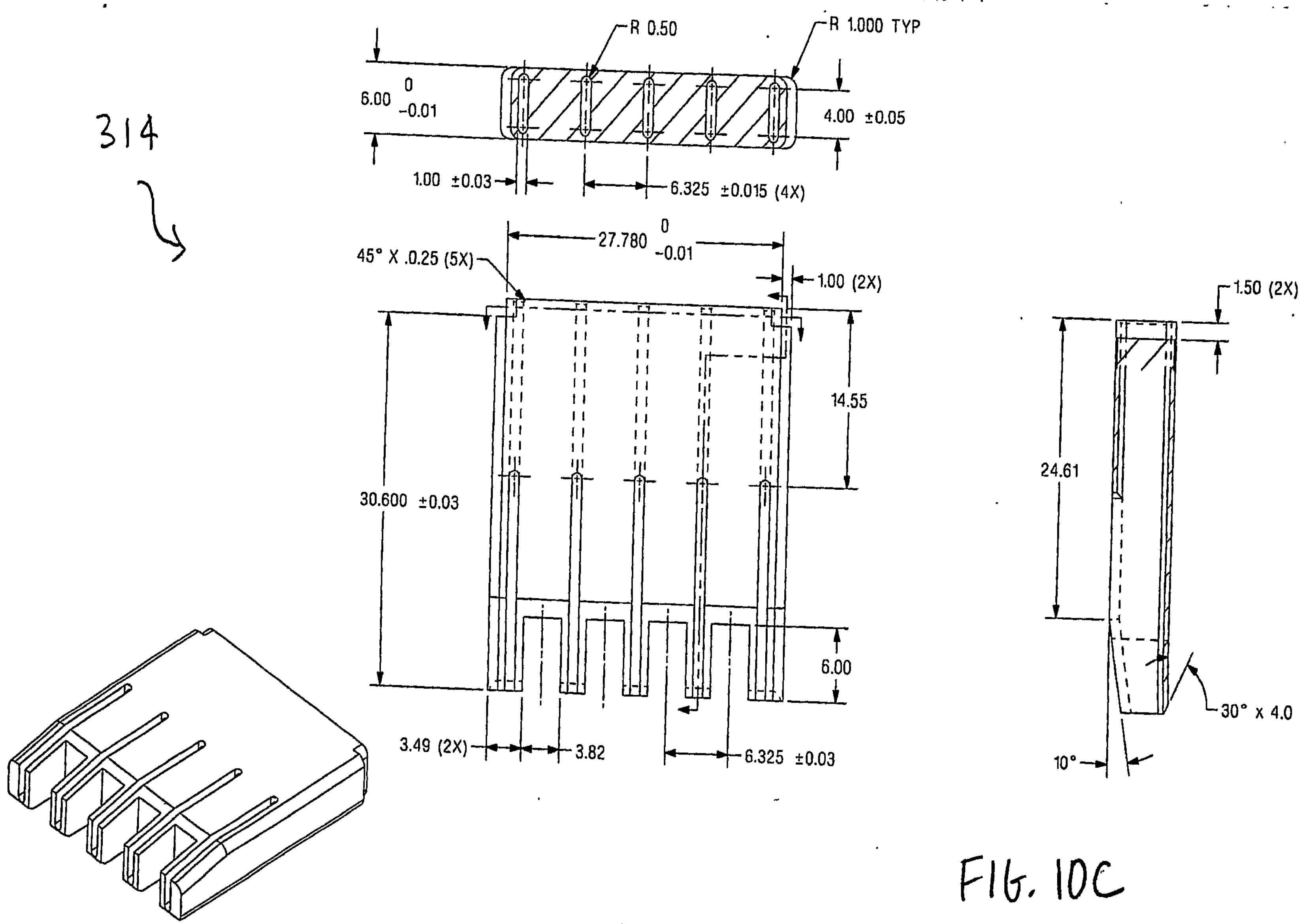

314
R 0.50
R 1.000 TYP
6.00 0 -0.01
4.00 ±0.05
1.00 ±0.03
6.325 ±0.015 (4X)
27.780 0 -0.01
45° X .0.25 (5X)
1.00 (2X)
14.55
30.600 ±0.03
6.00
3.49 (2X)
3.82
6.325 ±0.03
1.50 (2X)
24.61
30° x 4.0
10°

FIG. 10C